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The Cause—Not the Crime—Is the More Serious

When Trying to Stop the Practice That These Illustrations Represent

THERE'S a little book called "Protection Up to Date," published by a well-known circuit breaker manufacturer, that I like to read because it contains a lot of uncommon common sense about circuit breakers. It has no use for fuses, but inasmuch as we are not discussing here circuit breakers *versus* fuses, that doesn't matter and I can borrow this statement from that book to bring out the point I want to call attention to in connection with the accompanying pictures:

"Now common sense is not nearly so often found in people as it is in a highly-organized piece of machinery. The first apparatus we built was as *stupid* as a fuse, then gradually we trained it," etc. The operator who is determined to get a job done and does not think much about the nerves of the machine he is using, often believes the fuse is *a stupid thing* that works all right on less than its rated current but goes out on every provocation above that rating and causes him trouble at just the wrong time—that is, when he is working the circuit to its limit. The result is that in desperation and disgust he does one or more of the things that are shown in the above pictures, and commits a crime on fuses that the insurance companies will not forgive and which some states, through industrial commissions, have made a criminal offense punishable by fine and imprisonment.

The practice is bad—very bad in fact—but as fuses have been used in electrical work since the memory of electrical men runneth not to the contrary, and this practice still continues, the cause and not the crime is the problem to deal with. Fuses have their place in electrical circuits and their abuse will never be eliminated entirely until those who are likely to abuse them have a better idea of the reasons for protection in an electrical circuit against fires, possible damage to machines through overloads, single phasing of three-phase motors and the like. Instead of putting a man in jail for over-rating a fuse by soldering fuse wire to it or using a fuse element larger than intended, he should be taken aside and given a heart-to-heart talk on fuse construction and how easy it really is to overcome fuse trouble by using the correct fuse; also, how expensive it is not to do so.

Failure to provide the right kind of protection in a circuit and make it unnecessary to go wrong is about as bad as the crime of tampering with the rating of fuse elements. Manufacturers of renewable fuses are working on this problem and in the arguments they have used to sell this type of fuse they have without doubt brought about a much better understanding of the correct use of fuses, but the job is not yet finished. The subject of circuit protection is a big one and we are going to have a lot to say about it in future issues. If you have any ideas that you think are good, let's have them and by getting together and all going in the same general direction we will eventually get somewhere.

Practical Pete

A Glimpse Into the

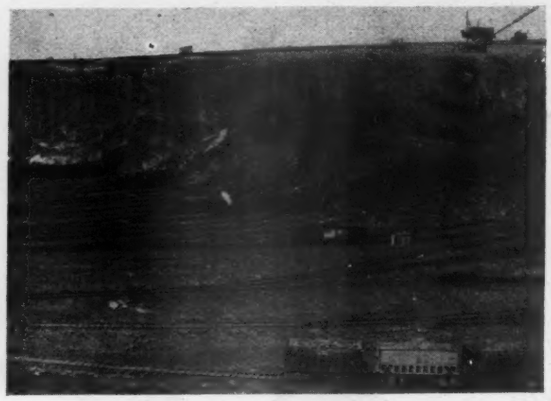
Portland Cement Industry

Where, because of the vast quantities of hard materials to be ground, the wear and tear on the machinery is so great as to require the employment of one man on repair work out of every five men in a cement plant.

IN THE manufacture of Portland cement about 2½ tons of material must be pulverized for each ton of finished cement. If powdered coal is used to burn the cement, about one-third ton of coal must be pulverized in addition for each ton of finished product. To avoid excessive wear on the bearings of the machinery involved, over a million dollars worth of grease and oil are used each year in this industry alone. Even with this care one man in every five employed at the cement plant devotes his time to repair work.

Portland cement was first made in England a century ago. It was so named because when hardened it resembled "Portland" building stone. Portland cement is made from lime, silica and alumina which ingredients may be secured from several different combinations. Some cement mills use cement rock and limestone; some use limestone and clay or shale; others use marl and clay; still others use blast-furnace slag and limestone. In each case the raw materials must be analyzed, blended and treated so as to make a standard, uniform product. Some of the cement plants are located near the quarries, although in other cases the raw materials are hauled considerable distances.

Cement passes through more than eighty distinct manufacturing operations from raw material to finished product. These include quarrying, at least eight crushing and grinding operations, a slow burning at a temperature of 2,500 to 3,000 deg. in a long rotary kiln as much as 240 ft. long, weighing over 600,000 lbs. and large enough to drive an automobile through, pulverizing the clinker in rotary ball-mills until it is finer than flour, sacking with

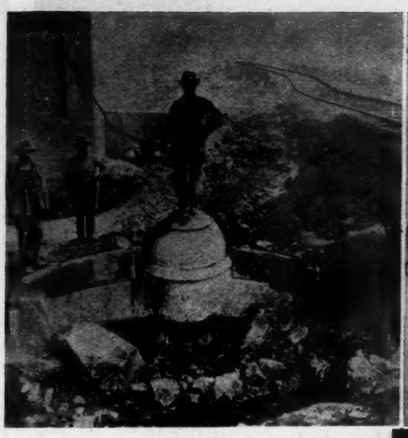


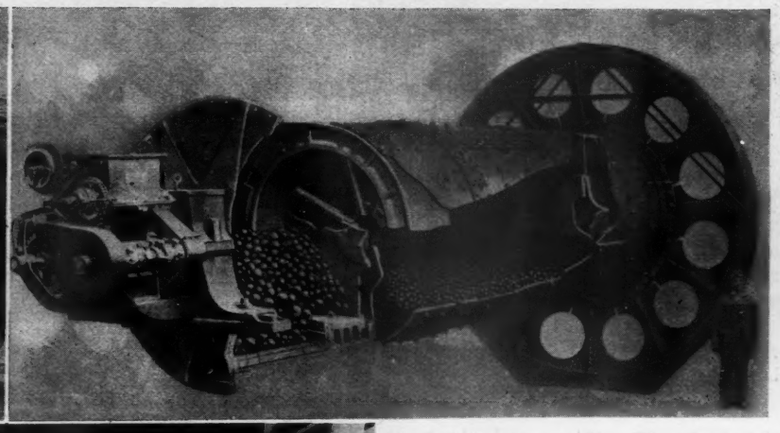
One of the quarries for a cement mill.

For every 94-lb. sack of cement it is necessary to quarry, mine or dredge over 200 lb. of raw material, including coal. Over 100,000 tons of rock are required daily to supply the Portland cement mills in the United States. In quarrying often 10,000 lb. or more of high explosives are fired in a single shot and loosen 50,000 tons of rock. This is loaded on cars by steam shovels and hauled to the mills. Over 15,000,000 lb. of dynamite and powder are required annually to produce raw material for the cement mills which often are located near the quarries to take advantage of a short haul of raw materials.

Even a moderate sized cement plant, such as this, represents huge scale manufacturing operations.

This is only one of the 120 Portland cement plants in the United States; the largest have a capacity of 100,000 sacks of cement a day. The sequence of some of the different departments which perform the eighty manufacturing operations is shown in the accompanying illustrations. These are: (1) Quarry; (2) rock crushers; (3) raw material storage tanks; (4) belt conveyor taking raw material to grinding mills; (5) raw grinding department where raw material is finely ground; (6) power house and boilers operated by use of waste-heat from the kilns; (7) rotary kilns in which clinker is burned at a temperature of 2,500 deg. to 3,000 deg. F.; (8) clinker conveyor; (9) clinker storage tanks and outside pile; (10) coal grinding mills; (11) clinker grinding department where clinker is pulverized to make cement; (12) cement stock-house; (13) auxiliary coal storage; (14) bag cleaning and storage; (15) cars waiting to be loaded; (16) packing and shipping departments; (17) reserve boiler house; (18) reserve power house. It will be noticed here that raw materials enter at one end of the plant and the finished cement is shipped out at the other.





Three types of grinding mills used in cement plants.

Almost 2½ tons of material not including the powdered coal are pulverized in the manufacture of a ton of cement. A large gyratory crusher (above) may weigh about 600,000 lb. and will crush 1,000 tons of rock an hour. This will take rocks weighing about 1,000 lb. and crush them down to small size. Eight crushing and grinding operations are required to pulverize the rock so that 85 per cent will go through a sieve with 200 cross-wires to the inch. This is burned in a kiln (below) and the resultant clinker which is glass hard, is again pulverized in the centrifugal mill (right) or the ball mill (upper right). These ball mills are about the size of a locomotive boiler and hold tons of steel balls which roll and grind the clinker into billions of particles to the cubic inch.

automatic machines, and shipping out. When pulverized, both before and after burning, 78 per cent of the material must shake through a sieve with 40,000 openings to the square inch—fine enough to hold water.

There are now more than 120 cement plants in the country, owned by some ninety companies. In two instances, the producing capacity of the plants runs over 25,000 barrels or 100,000 sacks, a day. At 800 sacks to the car, a day's shipment from one of these large plants may run to 300 carloads or more.

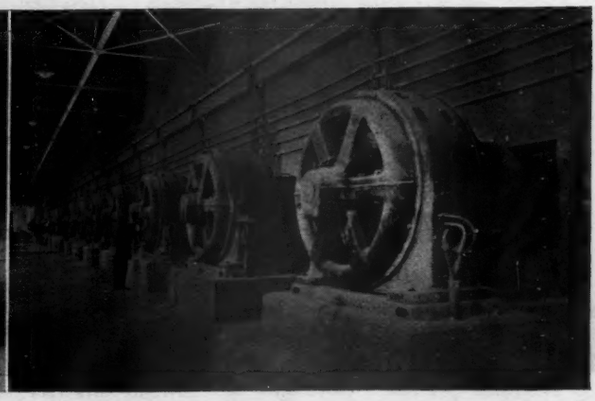
Within short distances of these large plants are others having not more than a tenth of their production. In more sparsely settled regions, other plants operate with a maximum capacity of four thousand sacks a day or less. Since cement is a heavy, low-priced commodity, freight rates play an important part in the delivered cost and the profitable shipping radius is relatively small. The demand for cement is seasonal, with the largest shipments in August.

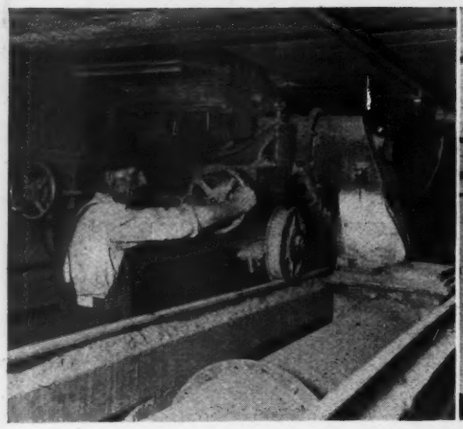
Some idea of the inter-relations of the cement industry to other industries is pointed out in the following facts:

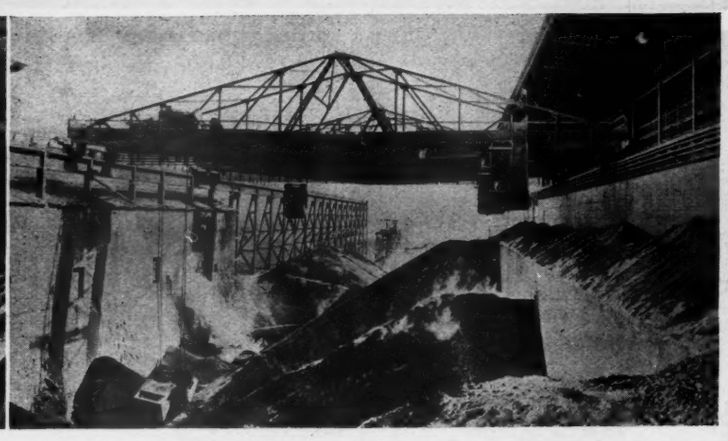
Each ton of cement requires more than one-half ton of coal to supply the heat and power necessary to produce it. According to the manufacturing census this industry is the fourth largest manufacturing user of coal in this country and the third largest user of power per dollar of prod-

Where the half ton of coal goes which is required to make a ton of cement.

Properly blended and pulverized raw materials are burned to a glass-hard clinker in the large rotary kilns (left) some of which are 240 ft. long and the material requires three hours to pass through. About a third of a ton of powdered coal per ton of cement (or oil or gas) is used for fuel and makes a temperature of 2,500 deg. to 3,000 deg. In some plants the waste heat from the kilns is used under boilers to furnish steam for power. The row of large motors operate mills on the other side of the partition for grinding. Over a million dollars' worth of oils and greases are required for lubrication of the machines and conveyors operating in the dust-laden atmosphere.







uct. Even a medium-sized plant will use as much coal as a city of 20,000 inhabitants.

Over 4,500,000 lb. of grease and 4,500,000 gal. of lubricating oil, costing over $1,000,000, are required in a year to keep the bearings, gears, and hundreds of miles of conveyors, which are used in the industry lubricated. Over 375 miles of belt conveyors and belting alone were worn out last year in the cement mills in this country.

Annually about 60,000,000 cement sacks, or one in every eight shipped out, are lost or destroyed.

Automatic scales (left) weighing and proportioning raw material, and the clinker storage (right).

During the pulverizing process the crushed raw materials are combined in proper proportions as determined by chemical analyses. The final pulverizing mixes these materials thoroughly before burning. After burning the clinker is stored in pits until pulverized. It is handled by traveling cranes and grab buckets. Material handling is a big problem in cement mills because of the numerous times the large quantities are handled in the eighty operations.

This pile of sacks are ready for the automatic bag-filling machines at the right.

After sacks are returned from the user they are inspected, repaired, tied with wire and stored ready for filling which is done through a flap or valve in the bottom. The automatic bag fillers weigh the material as it passes into the bag and shuts off at the exact weight. The operator then drops the bag on a belt conveyor which carries it away. A crew of four men can fill 8,000 sacks of cement a day. Formerly this work was done by men with shovels and a gang of four men could by hard work fill about 1,600 bags a day.

Over 60,000 bales of cotton are required to weave the cloth for sacks to replace this loss. The others are returned, inspected, repaired, the top tied, and then stored ready for filling. The sacks are tied while empty and filled through a valve or flap in the bottom by automatic filling machines. Over 55,000 miles of wire are required in a year to tie the sacks.

Due to the wide use of labor-saving devices and the increase in size of cement machinery used, each man employed produces 2½ barrels of cement, whereas 20 years ago he produced only one. Also, today a third less coal is required in the production of cement, than was formerly the case.

Although this industry, with its large quantities of explosive, high-temperature, crushing and pulverizing machines, and miles of conveyor belts, has many opportunities for serious accidents, safety work is so well organized through the industry that the accident rate is low. For example, one plant employing 350 men had only five minor accidents, causing only twenty days time lost in a year.

Last year 137,377,000 barrels (four sacks, 94 lb. each to the barrel) of cement were produced last year in the United States, which was a big increase over the previous year. Roads and buildings used a large part of this but there are many other applications.

EDITOR'S NOTE: Acknowlegement is made for assistance of the Portland Cement Association, Chicago, Ill., in compiling this material and supplying photographs.

SLEEVE BEARINGS have been condemned, sometimes justly and sometimes unjustly, from design and operating standpoints. That they have been abused and that part of the criticism directed toward them is due to this abuse, few will deny. How far the effects of this abuse can be eliminated in sleeve bearings by the operator and the maker, is of most interest to the user and in this article sleeve bearings are discussed from these standpoints.

Ways to Cure

Sleeve Bearing Troubles

With Construction Details of Motor Bearings and the Good Points of Sleeve Bearings That Are Sometimes Overlooked

By R. PRUGER

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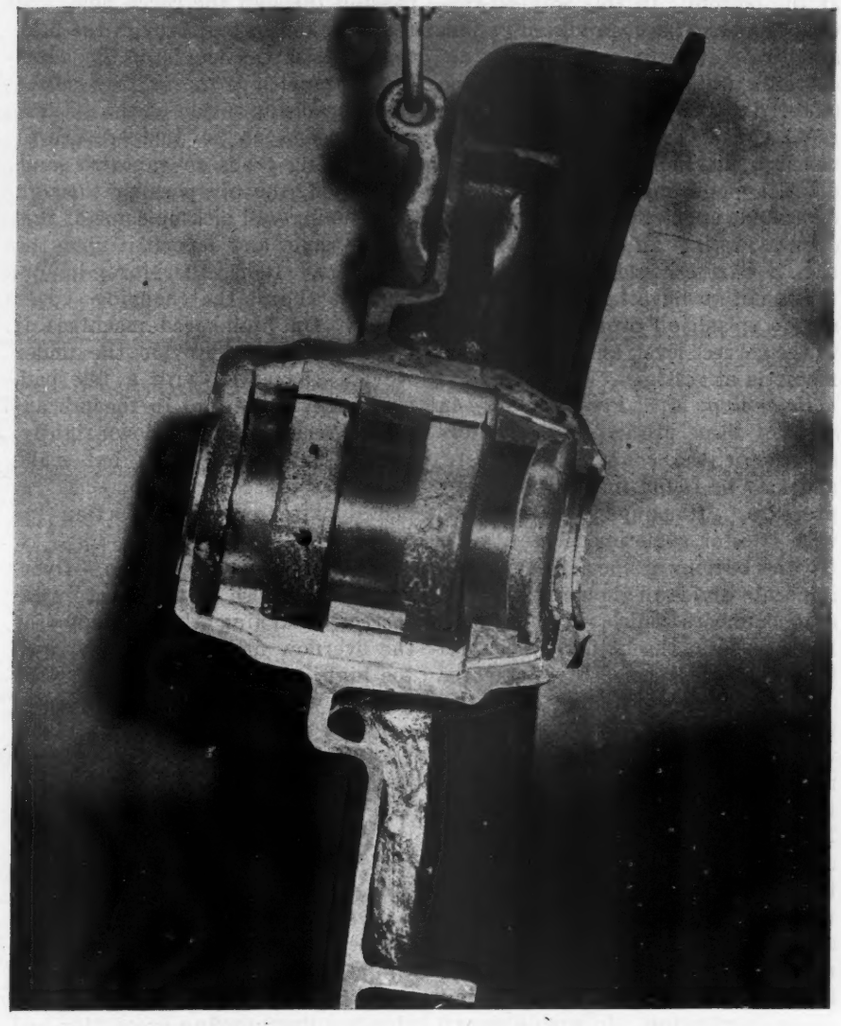
THE sleeve-type bearing with oil ring lubrication is widely used on industrial motors in all classes of service. Perhaps due to its ability to stand abuse, as much as to any other cause, it has in many instances been abused by the designer, the manufacturer and the user. The result of this abuse has been a certain amount of trouble with sleeve bearings. In some quarters this trouble has been accepted as inherent in the sleeve bearing, whereas it is in reality something that can be corrected. In this article some of these faults and the corrective measures are discussed.

Remedies Which Are Applied for Oil Leakage

Trouble Due to Oiling.—An investigation of a number of cases has revealed the fact that quite frequently oil troubles may be traced back to the oiler. Some attendants seem to be of the opinion that motors require oiling several times a week or oftener. This may be true if oil escapes in large quantities. In such a case, the matter should be investigated so as to cure the defect rather than continue the evil and favor it by feeding in more lubricant. Motor housings are usually provided with an oil overflow, that indicates the correct level. Under no consideration should this level be exceeded, as it will only cause the oil to overflow, probably into the motor, by way of the clearance between the shaft and the housing bore. Oiling the motor while it is in operation is not good practice and may produce overflowing, since a certain amount of oil is held in suspension by the ring and the bearing. When the motor comes to rest, this oil will drain back into the oil well, and if in excess of the right amount, may overflow.

Bearing housings are also equipped with a slot on top, to permit assembling of the oil ring. Oftentimes this slot is rather narrow and if an oil can is used with a large spout which does not enter into this slot, it usually happens that the oil is splashed over the housing and runs down on all sides, dripping off



This illustration shows one-half of a standard split bracket with grooves in the bearing housing walls to prevent leakage of oil at the split.

THIS IS THE FIRST of a series of articles on bearings of the sleeve, roller and ball designs, that will give the advantages of each compared with the others from the standpoint of meeting the wide range of service conditions in industrial work. INDUSTRIAL ENGINEER invites users and manufacturers to contribute their comments on the information presented in this series from the practical standpoint of improvements in bearing operation that actual service has shown. —EDITORS.

at the bottom. In this way oil-covered surfaces are produced which are directly in contact with the air currents which are drawn into the motor by the blower. These currents usually travel at considerable velocity, picking up small particles of oil and oil vapor which is again deposited upon the windings, producing in time an oil-soaked condition. Care should, therefore, be taken not to have housings too full nor to splash oil over them, but fill to the correct level, and slowly, while motor is at rest.

Balancing Air Pressure.—If in spite of these precautions oil enters the motor the cause is elsewhere, and may be found in unbalanced air pressure. Housings are provided with two, or sometimes three, seats for the bearing proper. These bearing seats divide the housing into several chambers which, in turn, have holes cored at the bottom to connect them. If these holes are not cored out correctly, which may occur due to shifting of the core in some way when the casting is made, these communicating openings may be entirely submerged by the oil level. Now, the action of the blower produces a partial vacuum around the bearing housing on the inside of the motor, drawing air from the chamber next to the inside of the motor and thereby raising the oil level in this chamber. This may cause overflowing. In such a case it will be found advisable to chip a few small grooves in the bearing seat, well above the oil level, so as to establish a balanced air pressure and free travel between the chambers in the housing. This point is quite essential and must not be overlooked.

On Westinghouse motors this balancing of air pressure is taken care of by coring in a communicating channel at the top of the housing, where this is of the solid type. Split housings have grooves cored in at the sides, which not only establish communication, but at the same time prevent oil from creeping across the surface of the split.

Closing Oil Ring Slot Tightly.—While this communicating channel accomplishes the balancing of air pressures, it must be remembered that cored holes cannot be made unless they have a fairly large cross section, for practical reasons. If we have, therefore, to deal with a high-speed motor, a considerable amount of air is drawn through the housing, entering by way of the oil-ring slot, passing through the cored hole, and reaching the motor through the bore clearance at the inside of the housing. Inasmuch as the oil ring causes considerable agitation of the oil and, furthermore, as the temperature of the bearing tends to vaporize some of the oil, the air passing through the housing will pick up some of this fog or vapor and deposit it upon the windings. It is, therefore, important to keep the housing cover closed. On high-speed machines it is customary to provide the under side of the cover with a felt pad, and sometimes to go to the precaution to screw the cover down tightly. Do not miss this point, but make sure that the cover is correctly replaced after each inspection or oiling.

Incorrect Over-flow Fitting.—Overflowing may also be produced by incorrectly tapping the housing for the overflow fitting. If it is tapped too high, or at an upward slant, the oil level will be registered above normal and may thus reach the inside bore in the housing and cause overflowing. A check should, therefore, be made against the lowest point of the inside bore in the housing and the oil level as indicated by the overflow plug, to verify its position.

Dust-proofing Precaution.—Felt washers around the shaft are oftentimes used on both inside and outside faces of the housing. However, this is a dustproofing precaution and while it will help in a measure to overcome oil leakage, it cannot be looked upon as a permanent cure. Felt will in time become oil soaked and finally permit oil to pass. It will render service as a dustproofing device, and, if it is designed correctly, will also prevent overflowing when the housing is filled too full, but it should not be depended on for more than that. If used as a lining or padding under covers which are screwed down it will be found useful, since it is kept under pressure and an air-tight packing may be produced. However, if felt is used around the shaft, its function is only as stated above.

Quality of Lubricant Used.—The quality of the lubricant is likewise a feature which deserves consideration. Some oils will produce more or less foaming at high speeds. This foam may reach the housing bore, and thus enter the motor. A change of lubricant is the surest and best remedy in such cases. If that cannot be done, a baffle plate may be introduced inside of the housing to form a separating chamber, giving the foam opportunity to settle and quiet down, returning by a communicating opening at the bottom to the oil well. Foaming has been found to occur also on ball-bearing motors and after such a baffle plate was installed the trouble was overcome.

Oil Grooves.—Another safeguard is to get rid of the oil before it emerges at the end of the journal after having done its work. This is accomplished by machining an annular groove near the end of the bearing. This groove need not be more than ¼ in. to ⅜ in. wide, and from 3/32 in. to ⅛ in. deep, depending upon the size of the bearing and the quantity of oil in circulation. At the bottom of this groove one or more holes are drilled and free communication is established to permit the oil to run back into the oil well before it reaches the end of the bearing. This will considerably reduce the possibility of leakage and relieve the oil thrower on the shaft of much of its work. This is quite important, as the oil thrown off by the thrower against the inner housing wall will run down along the walls and may drip back upon the shaft beyond the oil thrower, whence it may reach the motor. In troublesome cases on very high-speed machines, it has been found expedient to introduce a brass sleeve pressed into the housing bore, and with the inside end slightly curled up, so as to form a small groove which needs to extend only around the upper half. This groove will carry oil flowing down the inside of the housing walls and once past the horizontal center line, it cannot get on the shaft but will drain down directly into the oil well below.

There are, of course, a number of other devices which may be used, such as air shields which establish communication with the outside air, drawing air currents past the housing face and thus preventing air from being drawn through the housing. However, if the housing is well sealed, the seal will be found quite sufficient to overcome oil leakage at all ordinary speeds, and even at high speeds.

Good oil will last almost indefinitely if kept clean and within normal operating temperatures, except for the small amount of loss due to some slight escape of vapor, which is unavoidable.

If air currents are excluded, no dirt or dust is carried into the bearing. There is no reason, then, why a sleeve-bearing motor should not operate with entire freedom from oil leakage and, therefore, freedom from winding failures due to oil. With the bearing in perfect condition, the necessary amount of attention required will also be greatly reduced and the time between oiling periods increased.

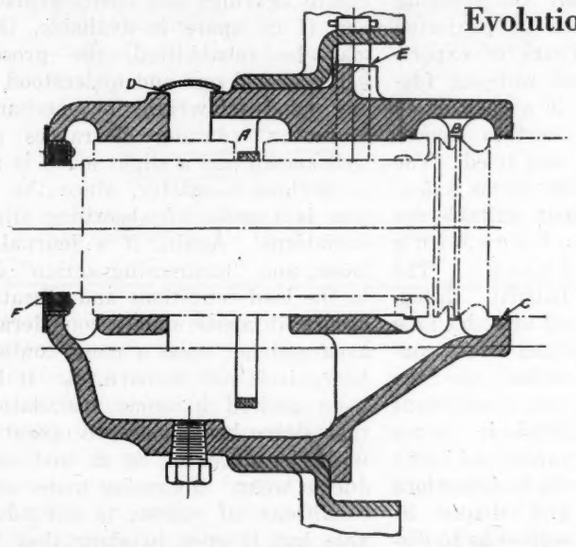
Advantages in the Use of Sleeve Bearings

Frequently long acquaintance and familiarity lets us forget merits and advantages, and dims our sense of appreciation and good judgment in our actions and dealings with the objects which, when correctly applied, have rendered useful service for many years. I believe that claims made in favor of one or the other type of a certain object should be thoroughly substantiated by actual facts and long trials under varying conditions, before setting aside a proven object in favor of a newcomer.

Considering some of the points that we find in the sleeve bearing, we may be able to draw comparisons and balance up against the ball bearing, which is sometimes given preference on one or two counts, such as oil trouble and attention required.

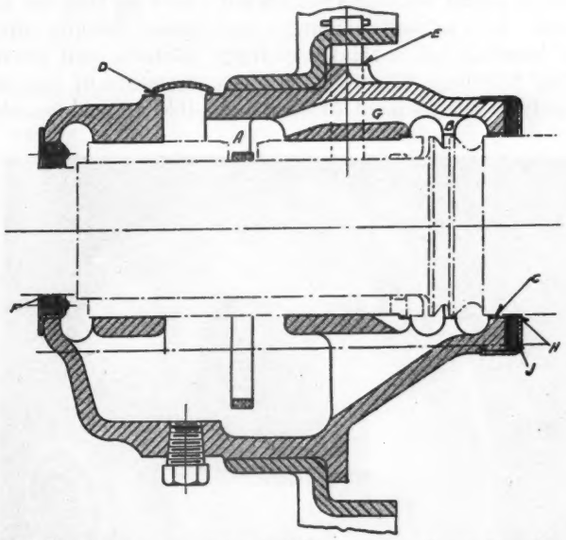
Evolution of the Leakproof Bearing Housing

Improvements are shown in unshaded sections at G, D and J in these drawings.

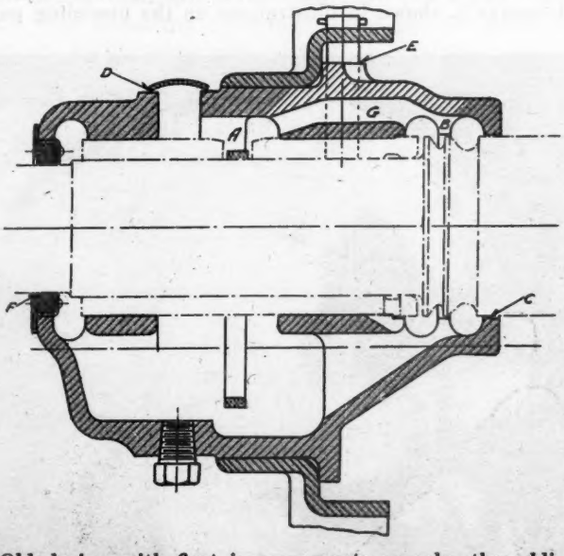


This design has become obsolete due to the five principal difficulties enumerated as 1 to 5.

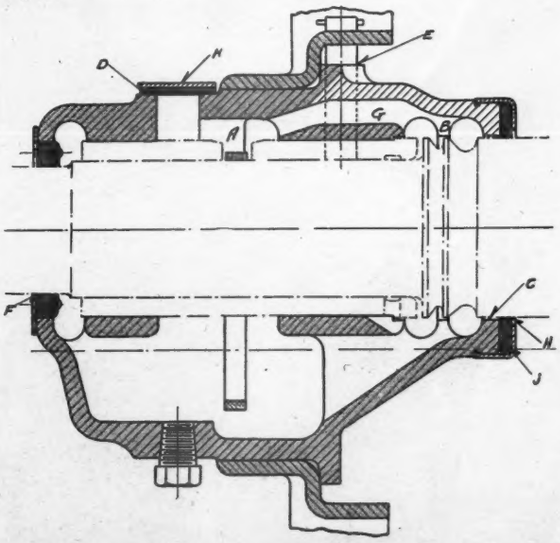
(1) No by-pass for air. Low pressure in chamber *B*, due to blower action, causes oil to escape at *C* if the oil level is temporarily raised too high. (2) Oil poured into the housing faster than it can escape from overflow plug will overflow at *C*, in spite of absence of blower suction. (3) Oil slops out of oil ring slot at *D*, especially at high speeds. (4) Current of air entering at *D* and escaping at *C* carries oil vapor into the motor. (5) Oil leaks out past steady pin at *E*. (6) Portion of shaft at *F* alternately covered by oil-soaked felt and exposed to air (due to end play), throws off a fine oil spray which is carried by the draft of ventilating air into the motor.



Old design improved by addition of an inner-bearing cap (J) to guard against oil leakage from careless filling of the oil reservoir, indicated as item (2) in the caption at the left.



Old design with first improvement: namely, the addition of a by-pass for air at G, to overcome the first cause of oil leakage indicated as (1) in above caption.



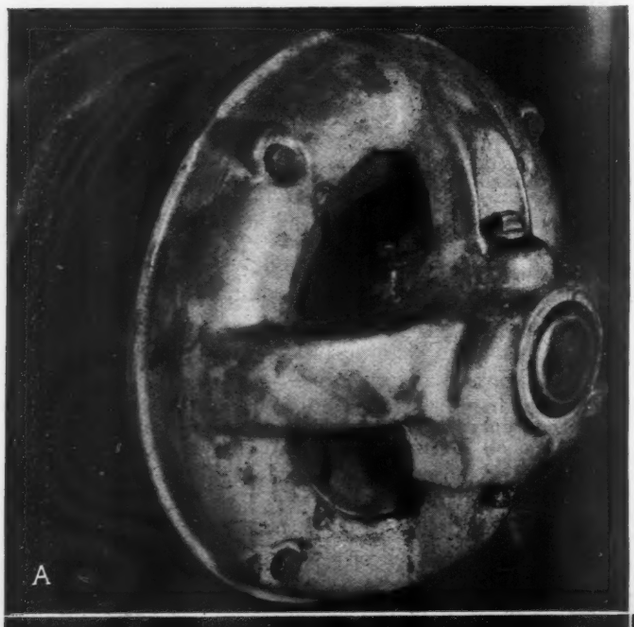
Old design with maximum possible improvements through addition of tightly closed oil ring slot by use of felt and steel oil ring slot cover at K screwed down.

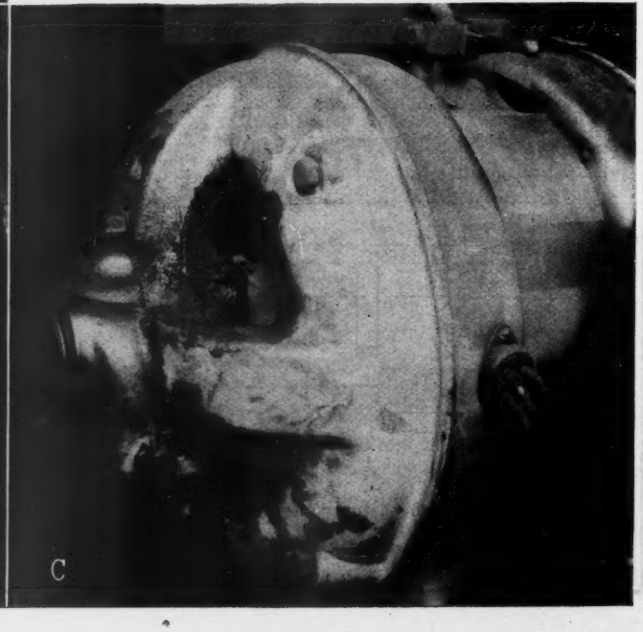
This partially corrects slopping out of oil and reduces current of air through the housing, indicated as troubles (3) and (4) in the upper lefthand caption. However, it is very difficult if not impossible to secure a tight joint at *D* by using a cover such as *K* held on by radial screws.

Inasmuch as this article is confined to electric motors and generators, we need not consider the item of friction losses in transmission, such as in lineshafting, which are admittedly very high where sleeve bearings are used and where proper alignment is hard to maintain. In the case of motors only two or three bearings need be considered, and these are either part of the motor itself or mounted on a common bedplate, which is an insurance for proper alignment. Furthermore, the small air gap makes it imperative that a good line-up be obtained. Hence, the friction losses become a matter of actual bearing friction not induced by mis-alignment. The sleeve bearing has a relatively high starting friction. However, this occurs only at the moment of starting, until an oil film is established, which requires less than one turn of the shaft. As the speed increases the friction coefficient drops rapidly, being only slightly in excess of what is found in ball bearings.

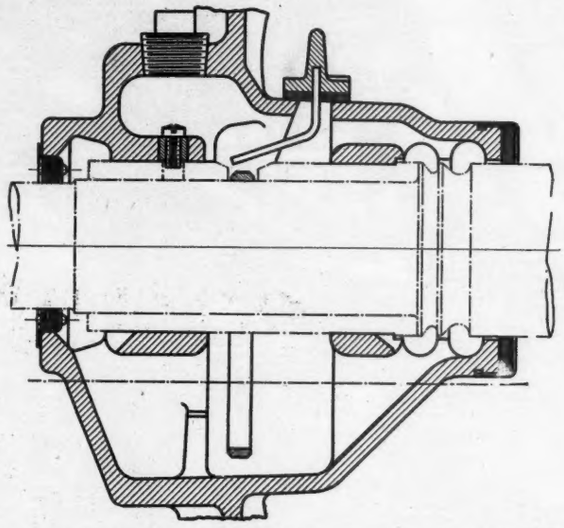
Bearing Surface.—Sleeve bearings, however, have the advantage of a large bearing surface, which is easily proportioned to take care of any load condition when designing the bearing. Thus, as in the case of geared or chain-driven applications, we know very closely the working load per square inch of projected bearing surface. Years of experience have established working factors so that we are in a position to base designs upon certain known factors, well proven and tried. The presence of the oil film forms a flexible or cushion element, suitable for absorbing shocks. The babbitt lining, after being "run in," conforms to the load conditions which may cause slight shaft deflections and shapes itself so as to distribute the pressure. Moreover, in some cases self-aligning bearings may be used, which readily present a uniform and large bearing surface to the load. This is quite in contrast to the point contact found in ball bearings, which is not yet fully understood when it comes to a matter of correct proportions regarding different classes of service, vibrations, and peak loads.

Wear.—No matter what type of bearing is chosen, wear is bound to occur. Then comes a time when replacement will have to be made. Sleeve bearings are easily replaced and if no spare is available, they may be rebabbitted, the process being an old one and understood by any good millwright or mechanic. Moreover, running clearances are well known and a slight error is not so serious a matter, since the oil film is capable of absorbing slight variations. Again, if a journal is loose, and "hammering action" due to the load conditions and vibration occurs, it comes upon a considerable area and not upon a point contact; hence it is not so harmful. It has been noticed in some installations that sleeve bearings were operating with clearances of 1/16 in. and over, due to wear. Operating under such conditions, of course, is not advisable but it goes to show that the period of usefulness to utter uselessness is distributed over a considerable length of time, which is an

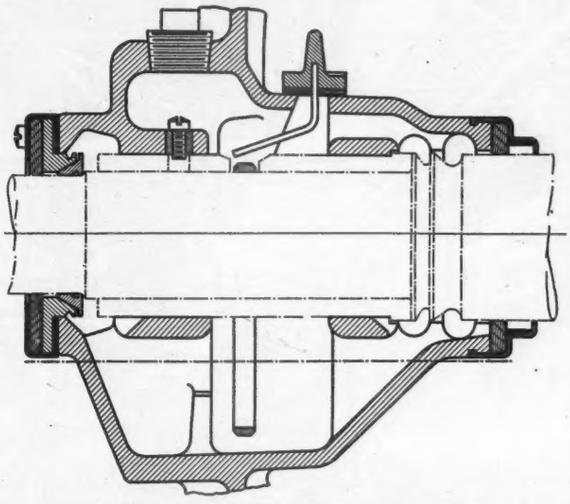




These three illustrations show leakproof bearing housings after a six months' running test without cleaning, as the dry dust adhering to the housings in the bracket arms shows. A is the front end of an 1,800-r.p.m. motor. B is the pulley end of an 1,800-r.p.m. motor, and C, the front end of a 3,600-r.p.m. motor. The construction of these bearing housings is shown in illustrations on the preceding page.



New design of housing that overcomes the five difficulties outlined as (1) to (5) on a preceding page.



New design with addition of leakproof devices to prevent leakage characteristic of motors running at high speeds.

important item in places where operation cannot well be interrupted from one end of the week to another. If trouble develops, it usually gives us signs long in advance of the actual break-down.

Replacements.—The matter of replacement is rather simple with sleeve bearings. Where gears or couplings are pressed on the shaft, split bearings may be used. Motor brackets are oftentimes designed in this manner, permitting removal of the bearing without dismantling the installation. This saves time. Where a middle bearing is used, the split sleeve bearing is the only alternative. Motor-generator sets with two rotors mounted on a common shaft and requiring a middle bearing, are easily taken care of in this manner. Outfits direct connected to turbines or blowers, particularly in places where space is limited, could hardly be made otherwise than with sleeve bearings. Split brackets are readily dismantled and the bearing removed without much difficulty.

Heating of the Journal.—Where loads are high and the pressure per square inch of projected bearing surface due to "dead load" is considerable, the sleeve bearing is without a parallel. Heating of the journal, if it occurs, can readily be cured by using gravity oil feed. The lubricant carries away the heat and can be cooled outside of the bearing. Practice has shown that water cooling is not required if the bearing is designed correctly and in many places where such a measure was originally installed it was never used and the journals have operated for years without water cooling.

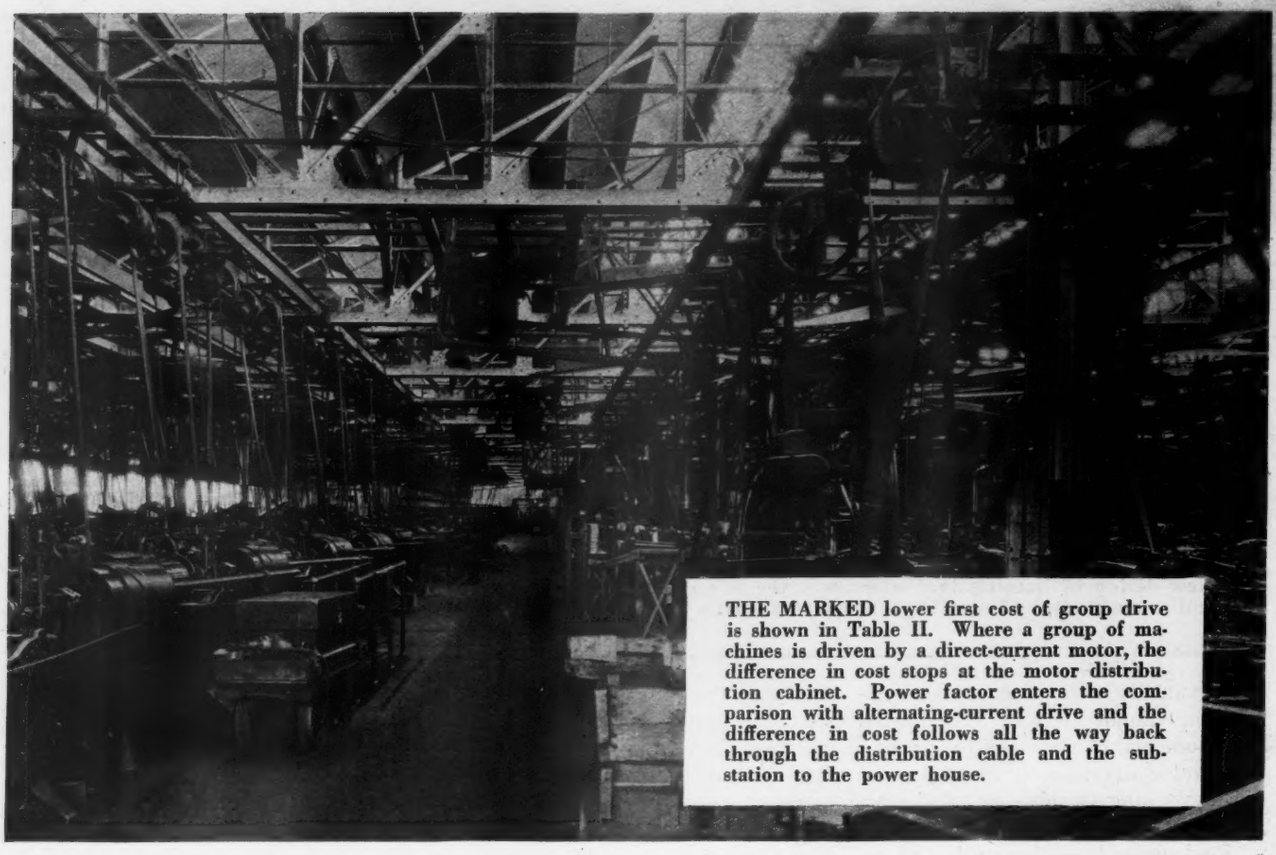
Stray Currents.—Another advantage found in sleeve bearings becomes prominent in cases where stray currents are found. The oil film assumes the role of an insulator to some extent, offering resistance to electric currents. Although this oil film is not effective to the extent of rendering the bearing immune to the passage of such currents the point contact, such as in ball bearings is avoided, thereby more effectively resisting the "pitting" found in some ball-bearing installations.

Handling Bearings. — Handling and manufacturing of the sleeve bearing is a process which can readily be taken care of in any well-equipped shop, without requiring extreme refinements and tolerances which are fractions of 0.001 in. This will be readily appreciated in repair work in the field, particularly in out-of-the-way places, where neither skilled help nor fine equipment is available. If it becomes advisable to carry spare parts the capital tied up is not great. Further, the handling and storing of sleeve bearings does not require unusual care and precautions. Babbitted bearing surfaces are not liable to become rusty, nor does the presence of particles of dust or dirt affect them. It is a simple matter to clean out all visible dirt.

Operating Temperatures.—Motors operating in very hot places are not so easily affected by temperature, since the liberal running clearances will permit a certain amount of expansion without influencing the operation. This point may seem somewhat far-fetched to some, but practice has shown that in cases of generators direct connected to steam turbines, ball bearings had to be made of special design to compensate for temperature; otherwise failure occurred. This trouble is foreign to sleeve bearings.

Initial and Operating Expense.—As to the matter of expense, the sleeve bearing is by far the cheaper. Initial cost could never be used as an argument against it. As to operating expense, objections are raised against the sleeve bearing principally on account of the damage caused by oil leakage. This feature, however, is not fundamental evidence against the sleeve bearing but evidence of some improper condition, in care or design or manufacture, which can be corrected.

Correct design and care are necessary, no matter what type of bearing is used; otherwise failure will occur. This is equally true of oil-ring sleeve bearings, waste-lubricated sleeve bearings, ball and roller bearings. While all of these types have a certain field, the oil-ring sleeve bearing undoubtedly meets the varied service required of the well-known, general-purpose, industrial-type motor. After all, it is a question of total expense, initial and operating, which should decide; and it has been found that by applying correct principles in the design of sleeve bearings and maintaining high standards of manufacture and maintenance, there is no other bearing which is so economical.



THE MARKED lower first cost of group drive is shown in Table II. Where a group of machines is driven by a direct-current motor, the difference in cost stops at the motor distribution cabinet. Power factor enters the comparison with alternating-current drive and the difference in cost follows all the way back through the distribution cable and the substation to the power house.

Service Conditions That Indicate

When to Use Group and Individual Drives

Together with Practical Operating Requirements and Supporting Data Developed from Long Experience in Mill and Factory Work

By ROBERT W. DRAKE

Electrical Engineer, McCormick Works, International Harvester Company, Chicago, Ill.

A DETAILED ANALYSIS of the reputed advantages of individual drives as compared with group drives will show that the latter have a much wider field of application than is commonly supposed. In the article by the writer in the February issue of INDUSTRIAL ENGINEER, the reputed advantages of individual drives were rather fully discussed together with the main features of applications wherein these drives are superior. In this article the reputed advantages of group drives are taken up and a comparison is drawn between the investment and operating cost of group and individual drives.

The lower first cost of group drive is very marked. With individual drive there is an increased cost due to the larger number of motors required and to the increased amount of wiring necessary. The cost per horsepower of motors, including controllers and branch circuit wiring, is likely to average, roughly, $20 for group drive, to $75 for individual drive.

As was pointed out in the preceding article, from three to five times greater installed capacity is required with individual drive; hence the cost of this item for a given installation will be in the ratio of $20 for group to $225 to $375 for individual drive.

There is also to be considered the difference in cost of the generating equipment. Where a group of machines is driven by a direct-current motor the difference in cost stops at the motor-distribution cabinet. Power factor enters the comparison with alternating current and the difference in cost follows all the way back through the distribution cable, the substation, to the power house.

The cost of generating and distributing equipment required to drive a motor horsepower is, with the exception of boilers, proportional to the amperes required by the load, not to the power required, and will vary from $275 for horsepower of load operating at an average of 80 per cent power factor (well-planned group drive plant including lighting

THIS IS the second of a series of articles that analyzes in detail the advantages of group and individual drives. The first article appeared in the February issue and discussed fully the principal reputed advantages of the individual drive. In this article Mr. Drake takes up the principal reputed advantages of group drives. The third article of this series will discuss details of layout and operation of group and individual drives.

load), to $340 for a horsepower of load having an inherent power factor of 50 per cent (average for a well-planned individual drive including lighting load).

Public service companies realize this fact even better than the power users who generate their own energy, and most large power contracts include a clause that increases the unit price for power when the power factor falls below 70 per cent to 80 per cent. Many contracts include a reduction of rate for power factors higher than that specified. When compared with such differences in cost of purchased power or with the fixed charges on generating equipment, the relatively small cost of the actual motors sinks into insignificance.

The above investment costs for handling an individually-driven load of low power factor assume that the power factor will be corrected by static or synchronous condensers, and include the cost of the necessary equipment. The writer believes that synchronous motors should be used wherever they are really suitable in either group drive or individual drives. It is exceptional to find suitable applications (without sacrificing reliability), for such motors, in sufficient aggregate capacity to bring the power factor of even a group-drive plant above an ideal figure of 85 per cent. Then, in the case of an individually-driven plant the additional power factor correction necessary to bring the average plant power factor up to the same figure represents an additional investment chargeable to power factor correction alone. This investment and the resulting fixed charges together with energy losses and maintenance costs are generally warranted in the case of a large, privately-operated system, or where power is purchased under a contract with a power factor clause. In the case of a small, privately-owned system it is cheaper to purchase non-standard generators designed for low power factor and install a heavier distribution system. Few plants consider the low power factor situation until the generators are bought and the plant is in operation; so synchronous or static condensers are generally in order.

The extra costs engendered by the inherently low power factor of an individually-driven factory are seldom recognized. If we charge these costs or the costs of the expedients necessitated to correct the low power factor against the individual drives, as is just, we have one of the strongest arguments for group drive.

Table I—Comparison of Motor Repair Costs

Motor Ratings	Cost of Motors, New	Cost of Rewinding	Cost of One Pair of Bearings for Each Motor
For one 50-hp. motor, 900 r.p.m.	$ 440	$ 250	$ 7.50
For five 10-hp. motors, 900 r.p.m.	900	550	20.00
For ten 5-hp. motors, 900 r.p.m.	1,400	830	22.00
For fifty 1-hp. motors, 1,200 r.p.m.	2,900	1,200	50.00

I. Principal Reputed Advantages of Individual Drive.

A. Elimination of overhead shafting and belting.
   1. Lineshaft friction losses eliminated.
   2. Maintenance of shafting and belting eliminated.
   3. Cleaner shop.
   4. Better light.
   5. Closer speed adjustment of the tool to the work.

B. Location of machines to suit the continuity of a manufacturing process without regard to the location of lineshafting.

C. When only a small proportion of the installed machines is to be operated (e. g., overtime or slack season) it is not necessary to operate idle shafting and belting.

D. On large work the tool may be taken to the work instead of the work to the tool.

II. Principal Reputed Advantages of Group Drive.

A. General advantages.
   1. Lower first cost.
   2. Lower electrical maintenance expense.
   3. Breakdowns with consequent delay to production less frequent.
   4. Possible to standardize more fully on motor styles and speeds, with consequent possibility of carrying complete line of spares and resulting in greatly decreased delay from such breakdowns as do occur.

B. Particular advantages when using a.c. power.
   1. Here the lower first cost extends back through the distribution system and to the power house.
   2. If the power is purchased, this is reflected in a lower unit cost for power because of the greatly increased power factor attainable with group drive.

Group Drive Has Lower Electrical Maintenance Expense

Routine maintenance and inspection of each small motor costs almost as much as for a large one. The cost of repairs does vary somewhat with motor size, but by no means in proportion to size. The comparison in Table I will bring this out plainly.

Now the number of repairs is far greater *per motor installed* for individual drive motors than for motors driving groups. This may seem surprising, for the individual motors generally do not run steadily; however, the fact is incontrovertibly demonstrated by experience and here are some of the reasons:

(1) If an extraordinary amount of power is demanded on an individually-driven machine by an uncommonly heavy job or by a machine adjusted too tight after overhauling, the motor is likely to "roast out." With a group drive the increased demand due to a few such machines will be much less per cent overload on the motor. It is very uncommon to have abnormal loads on all machines in a group occur simultaneously.

(2) The smaller sizes of motors, especially in the case of alternating-current motors, are far less rugged. On gear drives, many manufacturers furnish die-cast bearings which pound loose in the heads. Also, on the smaller motors used on individual drives there are partially-closed-slot windings which cannot be so thoroughly insulated from the core as is possible with open slot windings as furnished in the larger sizes usually applicable to group drive.

(3) In ordinary group-drive applications some trustworthy employee is delegated by the foreman to start and stop the motor. He can be taught, by very simple instructions, how to start and stop and what to do if the power goes off when machines are under load and the torque required to restart is beyond the capacity of the motor. Ordinarily a man will be selected who has been employed in the department for some years and such instructions once given need not be repeated at unduly frequent intervals due to labor turnover. In the case of individually-driven machines, everybody handles motors, the least intelligent as well as the most intelligent. The abuse which the motors get would be ludicrous, were it not so serious. Automatic devices offer the only protection possible against ignorance, but even automatic devices can-

Building construction and lighting are points to consider when selecting types of drives.

In manufacturing buildings as they are constructed nowadays, with walls that are all windows and with high ceilings, the shafting and belting necessary for an intelligently-planned group drive of 10 hp. to 50 hp. cannot be said to interfere seriously with either the natural or artificial lighting.

not eliminate such troubles. They only reduce them.

(4) Individual-drive motors are usually located where they are more exposed to accident than are group-drive motors, which are ordinarily mounted on the ceiling. Motors on the floor or mounted on a machine are more exposed to dust and dirt, which wear out the bearings. They require more frequent cleaning due to metallic and other conducting dust which works into the winding, causing grounded coils (especially on partially-closed-slot windings) and to water and to oil when these are present in the process. Foreign bodies such as metal chips, etc., are more likely to enter the air gap and "rip" the coils.

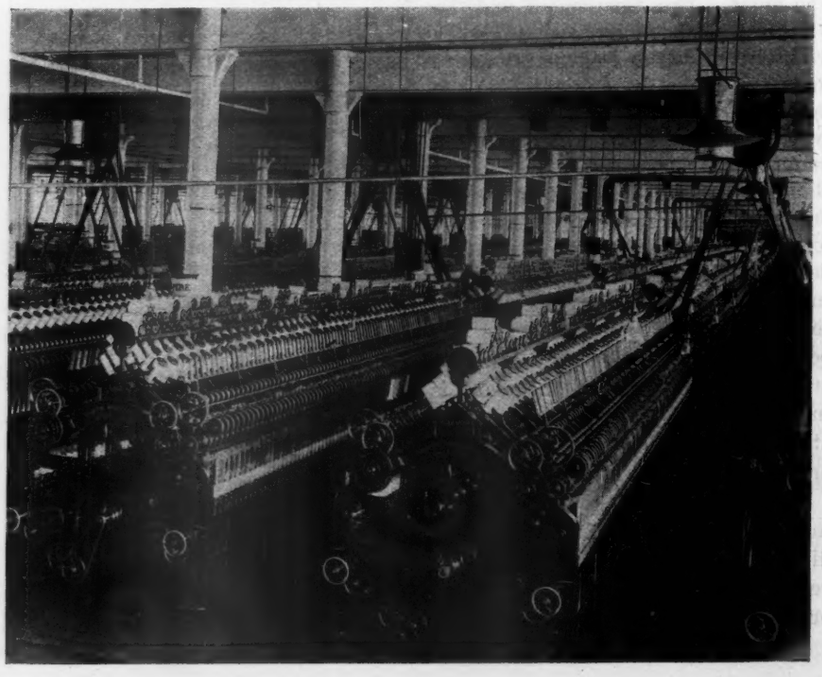
(5) Many individual drives are of necessity geared, which wears out bearings more rapidly than do belt drives. The life of bearings in belt drives under favorable conditions averaged eight years in one plant under my charge. With gear drives a life of that many months is not uncommon, and in one application six weeks service was all that we could realize with standard motors.

(6) Many individual drives are silent chain drives, which are excellent while the chain is in good condition. When one pin or pivot in the chain fails, however, the distance between teeth of the chain is increased at that point and each time this point in the chain passes around the motor pinion it strikes a hammer blow, the effect of which is astonishing. When it is necessary to continue such a drive in service for a few hours until noon or until shift-changing time, the motor not infrequently breaks down. If it runs through, the bearing shells are worn on the outside so as to be unfit for re-babbitting; the head is worn on the inside so that it must be replaced, since even a new bearing will be loose therein, and not infrequently the slot insulation is so worn at the end of the slot by the excessive vibration that a ground soon occurs.

The cost of routine inspection of each small motor (individual drive) is substantially the same as the corresponding cost for a large motor (group drive). The writer's experience shows that it pays to have a motor inspector visit each motor every day. This matter is further discussed in the third section of this series of articles.

The cost of repairs for each small motor (as ordinarily installed for individual drive) will average higher than the repairs on a larger motor driving a group of machines in similar surroundings. The unit cost of bearings, rewinding, and the like, is somewhat less for the smaller motors, but for reasons explained above, the frequency of repair averages much higher and the total average annual cost of repairs per motor is considerably higher in the case of individual drive. For example, in two large industrial plants with which the writer is familiar, one principally group driven, and one approximately 50 per cent individually driven, with the class of manufacturing roughly similar and the total number of motors in each plant approximately the same, the total cost of motor repairs in the plant where 50 per cent of the motors are on individual drives is more than twice that of the group-drive plant.

The above comments give a rough idea of the relative cost of maintenance *per motor*. The relative *total* cost of motor and starter repairs is harder still to approximate because of the great difference in service conditions, such as the average number of machines per group, and their location which involves the relative liability to injury from flying chips entering the air gap, and so on. For average manufacturing conditions, I believe that it is entirely safe to state that in a plant where individ-



Group drive arranged without the use of lineshafting.

By the use of two pulleys on each end of the motor shaft four machines are driven in a group. This scheme combines the advantages of group drive with some of the advantages of individual drive.

ual drive is carried to an extreme the electrical maintenance expense for motors and starters will exceed ten times the corresponding cost for an intelligently planned group drive.

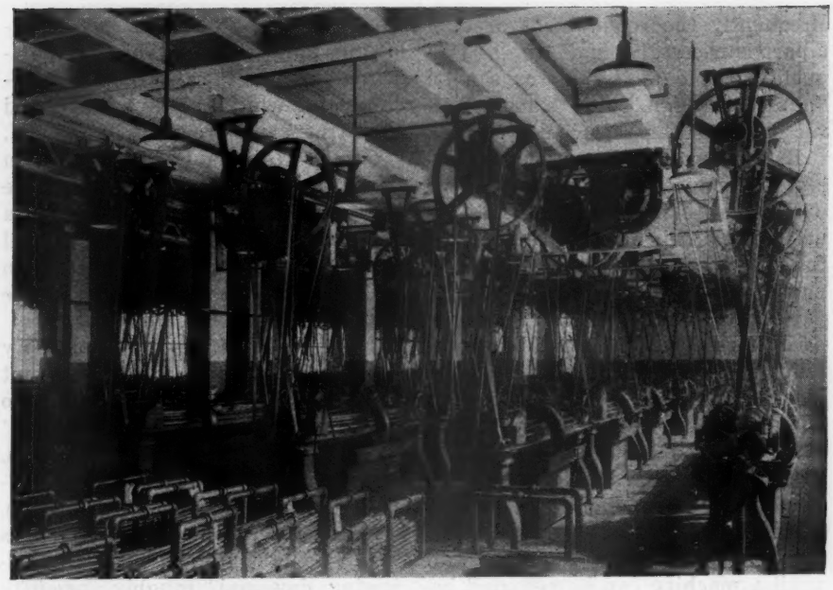
Before leaving this subject, let me call attention to the fact that the maintenance of motors alone is not the whole story The maintenance of shafting, pulleys and belting for group drives must be balanced against the saving in motor maintenance.

Reliability of Drives is an Important Consideration

The choice between individual and group drive in any given case should depend upon the total annual cost. However, the true relative total annual costs are not by any means approximated by the sum of interest, depreciation, taxes, insurance, power consumed, maintenance and repairs. Reliability is a factor which has an important bearing on total annual cost. In a large, highly-organized plant there are hundreds of drives whose temporary failure even for a few hours will interfere with the regular flow of production; there are dozens of drives whose failure for a few minutes means a loss per minute sometimes equal to the cost of the drive.

There are several ways of considering continuity of service. For applications where a few minutes' delay will cause large loss, the only certain insurance is duplicate units or connections with two independent sources of power supply. If loss will continue even though the remainder of the plant is temporarily shut down by failure of the electric power supply, duplicate units should generally be driven by steam, gas, Diesel, or gasoline engines. An example of the necessity for such standby service is afforded by pumps which supply the water for cooling blast furnace tuyeres, pumps for fire service and the like.

The next degree of insurance comprises drives which may be delayed for, say, one hour without undue loss. In many such cases in a highly-organized plant, delay for a working day means interference with flow of production; assembly, painting, packing, and even shipping will be interfered with. With skillful help well organized, and proper engineering on the original layout, such delays in connection with motor drives can be avoided by means of a reasonable number of spare motors and a reasonable stock of repair parts. Steel mills have been organized on this basis for years, but most industrial plants have not yet reached this point.



Different sizes of pulleys on the same shaft of a group drive will give several different belt speeds simultaneously.

Each machine in this room requires two widely different speeds which must be delivered at the same time. A group drive with different sizes of pulleys on the line shaft readily adapts itself to this condition. For an individual drive to obtain this result each machine would require either individual countershafting or gearing, or else more than one motor for each machine.

The first requisite is a spare motor identical and interchangeable with every motor in service. Spare coils, bearings, pulleys, pinions and the like are necessary for each spare motor, in order that a burned-out motor may be put into running order in as short a time as possible. There is always the chance that another identical motor may break down before the first is repaired and returned to spare stock.

The stock of spare motors required to fulfill the above conditions may be reasonable, or it may be prohibitively large, depending on whether rigid standardization has or has not been followed in purchasing motors. If the purchasing department is allowed to "shop around" and buy motors from a half dozen different manufacturers, if motors of various speeds, types or makes in the same horsepower are purchased, you may need half as many spare motors as motors in operation, which is generally out of the question. On the other hand, if after careful consideration one or at most two standard types and speeds of motor for each horsepower rating are selected and rigidly adhered to, even at the expense of some inconvenience in arranging a small proportion of the drives, the percentage of spares necessary can, in a large plant, be kept between 5 and 10 per cent of the installed motors. When a type of motor becomes obsolete and is no longer obtainable, it is necessary to purchase a spare with the first motor of each horsepower of the new standard. When a motor of an odd or "off-standard" speed is purchased for some special application a spare motor must also be purchased, unless the drive is unimportant. It is surprising how few odd motors it is necessary to have in a group-drive plant if a little ingenuity is used in devising expedients to avoid them. It may be claimed that it is not possible to bring a motor from a distant point in a big plant and install it on the ceiling on a group drive in one hour. To this I can only answer that in a plant under the writer's charge, having 500 motors aggregating well over 10,000 hp., the electrical department failed in this matter less than once per year on the average, before the war, and since the war with somewhat less skillful men (equally good foremen) the failures have averaged only 2½ per year. Most of these failures are due to two breakdowns occurring at widely separated points in one "trouble district" at the same time, to the occurrence of a second breakdown involving the same size and style of motor before repairs are completed on the motor first replaced, or to some similar cause.

The necessity for the immediate replacement of a defective motor is the exception rather than the rule.

Frequently the replacement of only a part is necessary, and quite as frequently the defective motor can be "nursed through," until a more convenient time for replacement.

Breakdowns with consequent delay to production are less frequent with group drive than with individual drive. This results partly from the factors discussed under maintenance and partly because the great variety of motor types and speeds in each horsepower required by individual drive makes it impractical to stock a complete line of spares, or even spares for all important drives. With group drive if one, or at the most two, standard speeds for each horsepower are adhered to, a complete line of spares is practical and it never becomes necessary to wait until a machine can be rewound before getting a drive back into production after a breakdown.

A quantitative comparison of the delays resulting from individual and group drives is outlined in the following paragraphs. This comparison is based on the two rooms of machines for which the investment and operating costs are given in Table II.

Group Drive.—Once in fifteen years a delay lasting less than one hour. Once in 200 to 500 years a delay serious enough so that it will last more than one hour, and the men will be sent home for the rest of the day.

Individual Drive.—Once every three months some machine is out of service for an hour or more due to motor or starter trouble.

Due to the great variety of speeds, styles and types of motors a complete line of spares is inadvisable. Consequently about half these delays result in a shutdown until the following day and, roughly, one-fifth involves a delay until a motor can be rewound. This may mean three days, or more if another rush rewinding job is ahead of it.

Table II—Comparison of Group and Individual Drive Costs for a Specific Installation

Total Cost of Drives	Group	Individual
Cost of shafting, countershafts, hangers and belting, motors, starters, branch wiring and pro-rated cabinet cost, including installation and overhead	$ 4,985	$13,400
Power factor of motor load in room, average	80%	30%
Pro-rata cost of mains from substation or power house to cabinet. I am assuming a moderate sized factory employing say 3500 men. Mean length feeders from power house or substation bus to manufacturing rooms 600 ft., voltage 440	450	1,200
Proportionate cost of power house equipment to serve room, including cost of reserve capacity necessary to assure service, and proportionate cost of power factor corrective equipment required to maintain 75 per cent power factor	13,350	14,850
Proportionate part of investment in spares and spare parts for motors, starters, controllers, etc	25	450
Total cost of above items	$18,810	$29,900
Operating Expenses Per Year	**Group**	**Individual**
Annual fixed charges on investment, interest, depreciation, insurance and taxes at 15% total first cost	2,825	4,490
Amount of coal burned or amount of energy purchased	.....*	.....*
Maintenance and repairs of belts, including belt replacements	$ 225	$ 25
Maintenance and repairs of shafting and countershafting	75	.....
Maintenance and repairs on pinions, chain, etc	.....	60
Maintenance and repairs of motors, starters and wiring	57	345
Maintenance and repairs of power factor corrective equipment	.....	10
Cleaning lamps and reflectors	30	15
Window washing	15	10
Painting room inside per year (pneumatic paint machine)	20	8
Grand Total (fixed charges plus operating costs)	$3,247	$4,963

*This is essentially the same for either installation as shown on page 59 of the February issue. The lower motor efficiency with individual drive offsets the lineshaft and belt losses. If one or two machines are only occasionally operated overtime alone, the annual losses in the power-factor-correcting equipment necessitated by individual drive will offset the overtime lineshaft and belt losses of the group drive.

Above I have discussed in a qualitative way, the relative advantages and disadvantages of group and individual drives. Each has its field where it is generally admitted to be unwise to attempt to apply the other.

There is a large middle ground where many installations of each sort have been made. To make the discussion clearer in some respects, I will give an approximate estimate of the total annual costs of operation for one manufacturing room, group driven, and for a room containing the same machines individually driven. It is useless to attempt any precise estimate of quantities for this purpose, for conditions vary with every industrial establishment and precise costs deduced for one plant are not always applicable to another. All that I hope to accomplish is to give a better idea of the relative importance of the various items which have entered into the above discussion.

I have chosen a room containing machine tools used in the production of rather accurate parts, interchangeable manufacturing, of course. This room contains twenty-three machine tools which can be driven in a single group requiring a 40-hp. motor, or they can be driven by twenty motors driving individual machines and one motor driving three machines. In the following comparison (Table II) all items which are substantially equal for the two drives compared have been omitted.

This comparison shows a difference in annual operating expense of $1,700 in favor of group drive. Inasmuch as there are twenty machines that can be individually driven, this annual difference amounts to $85 per machine per year. On at least half the machines in the room individual drive could not help in any way to increase output. Thus on the other ten machines, individual drive must save the equivalent of $170 per machine per year to justify complete individual drive of all of the machines compared.

In this particular case the logical solution, in my opinion, is individual drive for those machines where it will result in a real gain in output, with group drive for the remainder of the room, but in two groups, one small group being separate, since in this vicinity the handling of the work dictates the location of three machines which may be expected to work overtime during rush seasons.

How to Check Up On Insulating

Varnishes and Their Solvents

To Make Sure They Are Suitable for Coils and Windings and to Know When They Are Properly Applied

MR. HAZELTINE GIVES these practical suggestions and the reasons for them:

Keep the varnish tightly covered when not in use. Buy a hydrometer and use it. Determine the specific gravity at which the varnish works best for a particular job. Then take readings of the gravity every day before you start to use it and add thinner when necessary to keep the varnish at the proper consistency. When thinning be sure that varnish and reducer are at the same temperature. Add thinner slowly and stir it thoroughly all the while. When cold thinner is added too rapidly it is liable to throw the varnish base out of solution. Large quantities when put in too quickly often cause a like result. Warmth aids the union; hence it is better to have the varnish and the reducer at a temperature of between 70 deg. F. and 90 deg. F. After the thinner has been added, stir until properly mixed. There seems to be an impression that repeated thinning destroys the qualities of the varnish. This is not true. Remember it is the base of the varnish that gives you the insulation. The base does not evaporate. When adding thinner you are simply replacing that which has disappeared.

This is the first of a series of articles on insulating varnishes. The second article will take up varnishes and the equipment needed for application; the third, varnishes and their troubles; and the fourth, selection of varnishes.

By H. L. HAZELTINE

Engineer of Insulation, The Sterling Varnish Co., Pittsburgh, Pa.

THE INSULATION of electrical apparatus has always presented to electrical engineers and those in charge of repair work, many perplexing difficulties. If it were simply a matter of protecting windings against electrical stress, grounds or shorts, the solution would be comparatively simple. The fibrous covering, such as cotton or silk, over the conductors keeps them separate and provides a space sufficient to prevent any electrical breakdown as long as the covering remains dry. Unfortunately, however, this fibrous covering has a great tendency to absorb oil, water and moisture from the air. These substances draw in with them actually conducting ingredients, such as carbon dust, which soon provides in service a direct path for the passage of the electric current. Also in the winding of coils this fibrous insulation is often pushed to one side, thus bringing the conductors too close together and oftentimes into actual contact.

Furthermore, in moving parts such as motor armatures, the coils must be held rigidly in place in order to keep them from being thrown by centrifugal force. Wedges driven into the slots are not sufficient, particularly to prevent the throwing out of the commutator leads and the loosening of the coils at the pinion end.

It is evident that a liquid material which will penetrate the interstices of the windings, and upon drying will provide a coat impervious to the

action of moisture, oil, acids or alkalis, and be sufficiently hard to prevent the passage of hard particles of conducting materials, such as carbon or metallic dust, would be ideal. This is the function of insulating varnish.

Insulating varnishes have been for many years universally used in the construction of electrical machines and it seems strange that so little authentic knowledge concerning them is possessed by the men in actual charge of their application. They are indeed so little understood that the user often regards varnish as the cause of many of his troubles. In fact, varnish makes an excellent scapegoat for defects in insulation. The manufacturer (who has the only first-hand knowledge of his product) will advise to the best of his ability, and yet his information is often regarded with suspicion.

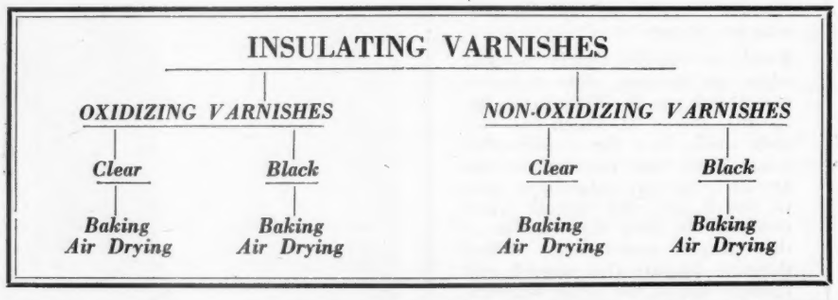
Nevertheless complaints, made in good faith, are received occasionally which show the vague general knowledge concerning this class of material. For example, one manufacturer of motors writes: "The black varnish we are using does not give any color on the coils." Investigation showed he had emptied a drum of thinner into his varnish tank and forgotten to stir it. Another wrote: "The varnish eats holes in tin," although it had been stored and shipped in ordinary tin cans. Another inquires as to the varnish to use on 9,000 volts service—nothing else being specified.

It is the purpose of this series of articles to clear up these misunderstandings and to assist the user in a more intelligent selection and application of insulating varnishes.

Varnish is a combination of drying oils, gum, drier and solvent. An insulating varnish may, therefore, be defined as such a combination of drying oils, gums, driers and solvents as to be a high dielectric, wet or dry, both in ohmic resistance and disruptive strength. Its solvent before evaporation should answer the same requirements. The coating once applied and dried should be adherent, binding and mechanically strong. Furthermore, it should not lose either its electrical or physical qualities when subjected to the continued action of heat and electrical stress—developed by the machine itself—combined with the action of acids, alkalis and moisture which may be present in the surrounding environment. It should be remembered that the function of insulating varnish is largely a mechanical one. It is a general axiom in electrical work that if we correct mechanical difficulties, the electrical ones will take care of themselves.

It is very difficult to make an absolutely definite classification of insulating varnishes. The distinction between the classes is vague and there are many cases of overlapping; hence any grouping which we make must be regarded as purely arbitrary and for the purpose of pinning our attention to certain types of materials.

Classes of Varnishes.—Insulating varnishes may be divided into two broad classes: (1) Those which dry by simple evaporation of the solvent. (2) Those which after the elimination of the solvent harden by reason of a chemical change in the structure. Such products are said to dry by oxidation, that is, the presence of oxygen, or air containing oxygen, is required throughout the drying process. These classes fall into two color subdivisions—clear and black—which are again separated into two groups—air drying and baking—as shown below.



This grouping has its faults since it is quite obvious that some air drying varnishes may be baked and that almost any baking varnish will air dry if given sufficient time.

Another classification could be made according to the nature of the vegetable oils used in the manufacture of the varnishes. The principal oils are linseed and chinawood. There has been much discussion in recent years as to the relative merits of these two materials, and many extravagant claims have been made for varnishes containing the latter oil. It is not our intention to take sides but we will endeavor to point out the characteristics of each oil.

It is true that chinawood oil dries more quickly and requires the presense of a lesser amount of oxygen than does linseed oil. It will even dry under water and this characteristic has been the basis for the claims that the oil dries by polymerization, that is, by a readjustment of the structure of the molecules entering into its composition, and not by the absorption of oxygen. However, it must be remembered that water contains a certain quantity of free oxygen and this undoubtedly acts upon the oil and causes it to dry. Furthermore, if the statement were true, chinawood oil varnishes would not skin over on the outside but would dry uniformly throughout. This has not been our experience. We have found that a skin forms during the drying leaving a certain amount of undried varnish underneath and this has also been the experience of others.

Equally good varnishes can be made with either oil, but aside from the quicker drying of the chinawood oil there is no characteristic which makes it superior to linseed oil. It must be remembered that many so-called chinawood-oil varnishes contain only enough wood oil to render possible the use of the name. Furthermore, it must be remembered that a greater percentage of gum, particularly common rosin, may be used in their manufacture. This of course results in a more brittle product. It is a question whether the rapidity of the drying of the chinawood-oil products is due to the excess gum or the nature of the oil.

In general, the quicker the drying of any varnish the shorter is its life when exposed to operating conditions where it is subjected to continued heating and cooling and the vibration of the machine itself. Again, chinawood oil is a product of foreign manufacture and hence we are unable to control either the price or its purity. Linseed oil, on the other hand, is a more nearly native product and its purity can be very closely regulated.

We could group varnishes according to the percentage of drying oil contained. You have doubtless heard the expression, "long oil" or "short oil" varnishes. A varnish is said to be long in oil when the amount of oil contained is large in comparison

with the amount of gum. When this condition is reversed, that is, when the material contains a large amount of gum and a small amount of oil, it is said to be short in oil.

In the clear, or transparent varnishes, rosin is the commonest gum used. This gum is naturally a very brittle substance and hence varnishes containing large amounts of it have a tendency to become brittle and crumble. Black varnishes are, generally speaking, less oil resistant than are the clear varnishes, but they are much more proof against water and acids. Their color is derived from black gums. These gums are usually more flexible than those used in the clear materials; hence they will generally withstand continued heating better.

What is Meant by Life Tests.—There has been a demand occasionally for materials that will withstand so-called "life" tests. These tests are made by coating paper or cloth with varnish and baking in an oven until the film cracks when the sheet is bent about a mandrel of a given radius. The number of hours required before the material cracks is a measure of the "life" or the "flexibility" of the varnish. The demand has been for materials that will stand this test for several days, and even weeks. To obtain the results desired, the manufacturer has reduced the amount of drying oil and increased the percentage of gum, using very soft pitches for this purpose. Varnishes having great length of life have even been made with no oil at all. They are simply solutions of the soft pitch in suitable solvents. They would be classed as non-oxidizing varnishes, inasmuch as they dry solely by the evaporation of the solvent.

It is a peculiar thing that although such materials stand up very well on laboratory tests for flexibility, as described above, they do not stand up in service as well as the long-oil products do. It seems that machines in operation are subjected not so much to a constant heat as to repeated heating and cooling, and also to considerable vibration. The short-oil products, or those containing no oil, are dried out in service and pounded by the vibration until they pulverize, whereas those long in oil do not show this characteristic. They seem to have the ability to stretch with the expansion and contraction of the metal in the machine, and because of this are not affected by the vibrations. We call this quality "elasticity" to distinguish it from "flexibility" or "life." It cannot be determined by test but shows up only in service.

The pitches used in the non-oil products are similar to the solid compounds which are sometimes used for the filling of coils. These solid compounds are brought to a liquid state by heat and then applied to the windings. As they cool they solidify, but of course will resoften when subjected to heat. Hence, varnishes consisting of a solution of these products will soften and show a decided tendency to flow when exposed to the heat developed by machines in service.

Points on Long-Oil and Short-Oil Varnishes.—Let us now make sure that we have these facts straight as far as we have gone. Long-oil varnishes, either clear or black, are strong and adhesive. They have considerable "elasticity" and will withstand much vibration without crumbling. Short-oil clears have little "elasticity" or "flexibility." They require a short bake and are very strong mechanically. Short-oil blacks, on the other hand, have little "elasticity" but maximum "flexibility." They have little binding power. Both of the last two types show a decided tendency to soften and flow under heat, a characteristic which is, in many cases, objectionable.

Air-drying varnishes are generally those containing very little oil. Oftentimes they are simply solutions of solvent and gum. If they do contain oil there is so little present that they can be said to dry by the simple evaporation of the solvent. They have little strength, flexibility or elasticity and are used mainly for finishing where added protection is needed against external conditions such as oils, acids, water or alkalis. Generally speaking, the faster the varnish dries the more brittle is the final coating.

Table I.—Information needed to know when a thinner has a "narrow cut." See Fig. 1.

DISTILLATION RANGE OF STERLING REDUCERS.						
TEMPERATURE IN DEGREES CENTIGRADE.	PERCENTAGES DISTILLED OVER					
	Reducer F. 181	Reducer F. 160	Reducer F. 149	Reducer F. 50	Reducer F. 100	Reducer F. 75
45°						
50°	1st. Drop.		1st. Drop.	1st. Drop.		
55°						
60°	1%		2%			
65°						
70°	4%		4%	1%		
75°						
80°	9%		10%	3%		
85°						
90°	21%		18%	7%		
95°						
100°	37%		32%	13%		1st. Drop.
105°						
110°	58%		48%	23%		4%
115°						
120°	71%	1st. Drop	65%	38%		15%
125°						
130°	81%	5%	75%	55%		33%
135°		24%				
140°	88%	69%	85%	81%	1st. Drop	49%
145°		89%				
150°	92%	94%	93%	94%	9%	68%
155°		97%				
160°	94%	98%	95%	95%	48%	80%
165°						
170°	96%		96%		72%	89%
175°				97%		
180°	97%		97%		86%	93%
185°				98%		
190°	98%		98%		92%	96%
195°						
200°					95%	97%
205°						
210°					97%	98%
215°						
220°					99%	
225°						

We have discussed so far the drying oils and gums used in the manufacture of varnish. There remains only a discussion of the solvent. This material is merely a vehicle used to spread the oils and gums uniformly over the surface or to carry these products, which provide the real insulation, into the interior of the coils. Once the varnish has been applied the solvent's function is over and it passes off into the air. Hence, in the drying of any varnish the first action is to drive off the solvent and the second is to oxidize the base, consisting of oils and gums, to produce a hard film.

It is obvious that the varnish should be supplied by the manufacturer at such a consistency and viscosity that its uniform application is easy, and that it should contain the least amount of solvent consistent with this. In other words, it should have the largest amount of base, or useful material, that is, oil and gum.

When the varnish is kept in open or partially-closed dipping tanks the solvent evaporates and must be replaced before the loss becomes too great. Otherwise the material becomes so thick and viscous that thinning becomes a very difficult, if not an impossible, task. It is sometimes found that after a varnish has been repeatedly thinned, it seems to flow more and possess less covering and filling powers, although having the proper gravity. It may also require a longer drying period. This is probably due to using a thinner with too wide a cut. The lighter fractions or chemical constituents have slowly evaporated leaving only the heavier ones. A point may thus be reached where the varnish at a given gravity does not possess the amount of base desired. When such a condition arises it is advisable to allow still more thinner to evaporate and use the varnish at some heavier gravity that trial shows will give the desired coating and consequent protection.

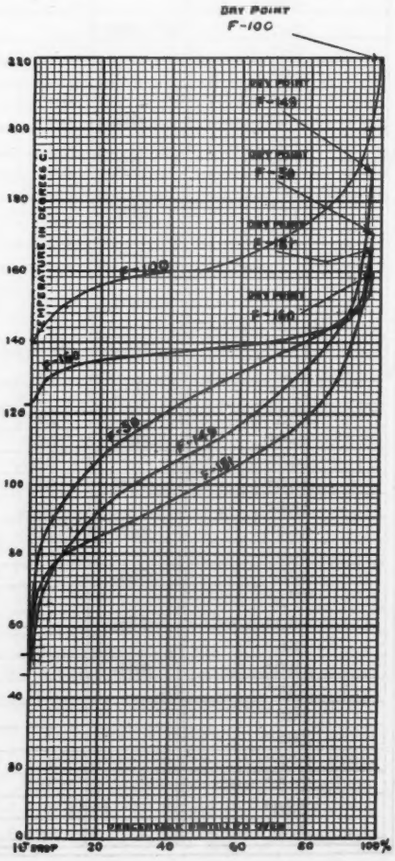
How to Select Thinners.—It is best in selecting a thinner to choose one having characteristics as nearly as possible like that used in the original varnish. Uniform petroleum distillates, such as benzine and petroleum spirits, are becoming more and more difficult to obtain and it is better to buy such products on specification. They should have a narrow cut, that is, they should contain no fractions distilling at either very high or very low temperatures. They should be free from paraffine, grease, or heavy oil, and should mix with the varnish without "livering" or curdling it.

Table I illustrates the meaning of the term "narrow cut." The curves shown in Fig. 1 are plotted from the values in Table I. These reducers having the flattest curve have the narrowest cut. Any reducer having a characteristic curve similar to these is suitable for varnish, provided it is of the same type as that used in the fresh varnish.

The apparatus, and its arrangement, used in the determination of these characteristics is shown in Fig. 2. The flask used is of the regular Engler type, with the side tube at the middle of the neck. Its capacity should be at least double the quantity of the liquid distilled. The side tube should be extended into the condenser where the water comes into contact with the inner tube. The thermometer is placed so that the mercury bulb is just even with this side tube so as to record the temperature of the vapor as it passes into the condenser. When one is also placed in the liquid it records a degree or two higher. The test is run as follows: Measure 100 cubic centimeters of the material to be tested in a graduated cylinder and then pour it carefully into the distilling flask. Use the same graduated cylinder to receive the distilled solvent. Place the flask in position upon a wire gauze and regulate the flame so that it just touches the gauze. As soon as the first drop falls into the receiving cylinder, record the temperature and so regulate the flame that the distillation goes on at the rate of about two drops per second. Then note the quantity in the receiver when the next 10 deg. point is reached on the thermometer, and for every 10 deg. thereafter. For example: If the first drop falls at 64 deg. C., the next reading should be made at 74 deg. C., and so on. Continue the distillation until the point is reached where the last drop is vaporized, indicated by a puff of white vapor in the bottom of the flask.

Fig. 1.—Curves plotted from data given in Table I.

The thinner with the flattest curve has the "narrowest cut." This means that it contains no constituents that distill at either very high or very low temperatures. It should also be free from paraffin, grease or heavy oil and should mix with the varnish without curdling it.

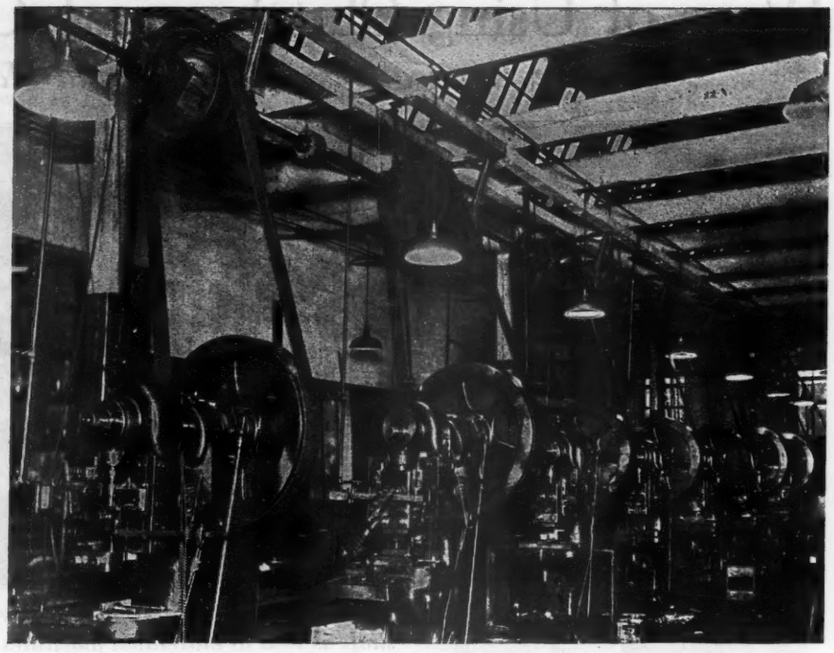


The solvents generally used in insulating varnishes are petroleum distillates (such as benzine and petroleum spirits), coal tar distillates, and turpentine, or a mixture of these. Wood or especially-denatured alcohol is also used to a certain degree. In the curves shown in Fig. 1 the one marked F-181 is the distillation curve for pure 62 deg. benzine; that marked F-160 is for coal tar distillate; F-149 is a combination of the two, 85 per cent benzine and 15 per cent coal tar distillate; F-50 is a combination of the two in equal proportions; F-100 is the curve for petroleum spirits.

Benzine (F-181) has already been partially described. It has the lowest solvent powers of any of the materials mentioned. On this account and because of its rapid drying, varnishes containing this solvent are especially adapted for use with enameled wire.

Petroleum spirits (F-100), sometimes known as turpentine substitute, has greater solvent powers than the lighter distillates. Its flash point is over 100 deg. F. and for that reason it is not dangerously inflammable at ordinary room temperatures. Inasmuch as it evaporates much more slowly than benzine, varnishes containing it are characterized by a smooth, even flow of the film and by great penetrative powers. Also, because of this the solvent does *(Continued on page 156)*

DURING THE past year there has appeared in INDUSTRIAL ENGINEER a series of articles dealing with problems associated with the installation and operation of mechanical power transmission equipment. These articles have covered belts, pulleys, silent chains, gears, speed reducers, rigid and flexible couplings, and friction and magnetic clutches and cutoff couplings. This article, which is a continuation of the series on clutches and cutoff couplings, takes up the information necessary when ordering and installing them and the operating conditions which are the most favorable. The purpose of this group of articles has been to present current practice in connection with the construction and application of the various mechanical power transmission elements and particularly to emphasize results possible when these problems are given more thought and care.



This battery of punch presses is driven directly from a lineshaft through individual clutch pulleys for each machine.

Ordinarily, unless countershafts are used, it would be necessary to operate the flywheel of the punch press continuously, even though the press were idle. With these friction clutches for each machine on the lineshaft, countershafts are eliminated and it is possible to cut out any number of presses and eliminate all friction losses except those due to the lineshaft and to the presses operating. Also, with such an arrangement as this, it is not necessary to start the driving motor under load, as all the presses can be thrown out at the friction clutches.

Practical Points To Consider When

Operating Clutches and Cutoff Couplings

So As to Obtain the Service Expected Without Interruption of Production

By FRANK E. GOODING
Associate Editor, Industrial Engineer

CLUTCHES and cutoff couplings, as pointed out in an article in the January issue of the INDUSTRIAL ENGINEER, are used for temporary or intermittent disconnections of sections of shafting machines or other equipment when it is desired to save the power loss which would occur if they were permitted to operate continuously. While the previous article covered their construction and application, this article will take up some of the practical points connected with the specifying, installation and operation of friction clutches and cutoff couplings.

Probably the most important consideration is to obtain a clutch or coupling of the proper size for the load. Equipment too small for the load is no doubt the greatest single cause of trouble. Friction clutches and couplings are rated, like flexible couplings, according to the horsepower they will transmit per 100 r.p.m. However, the total load of the clutch should be figured to include all possible overloads. For example, if a clutch is connected into a pulley driving a machine normally requiring 10 hp., but which may have a 50 per cent overload, the rating of the clutch should be at least 15 hp. to assure freedom from trouble.

Perhaps the most severe load on a clutch is given by the pulsations of a single-cylinder gas engine. This ordinarily requires a clutch with twice the normal engine rating per 100 r.p.m. Other severe service is in connection with stamping mills, punches, shears, mixing machines, pulverizing and grinding mills, rubber rolls, and other similar machines. One manufacturer recommends the following increases in rating because of the service requirements:

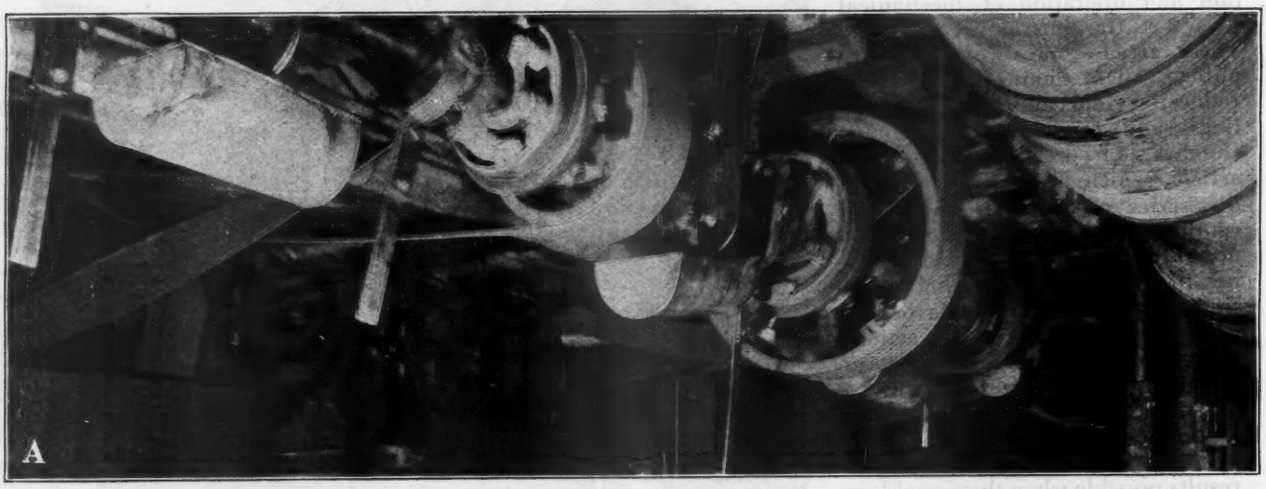
For single-cylinder gas engines, double the rated capacity of the engine, based on the same speed; for two-cylinder gas engines, add 50 to 75 per cent to the engine rating; for three-cylinder gas engines, increase 25 to 50 per cent in rating; for engines with four or more cylinders, an equal rated capacity.

Where clutches are attached directly to the engines the above conditions must be adhered to but where attached to driven or receiving pulleys, a slight reduction in capacity is permitted. In case of doubt it is well to consult the manufacturer of the clutch who will advise from his experience.

Any service where the movement of shafting is not continuous is out of the ordinary and in selecting clutches conditions must be analyzed carefully and a clutch of sufficient capacity provided. Some of the special considerations are found in connection with a clutch which is re-

Ways of Using Clutches and Cutoff Couplings

Nine Applications of Friction and Magnetic Units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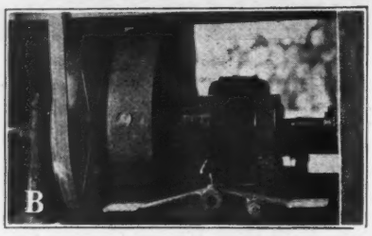
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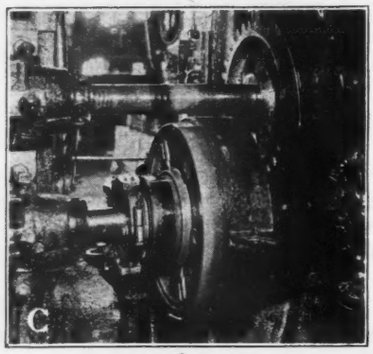
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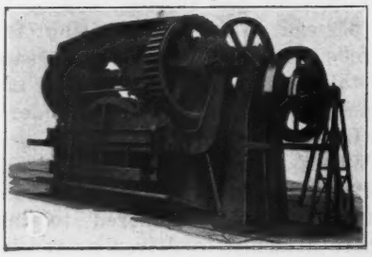
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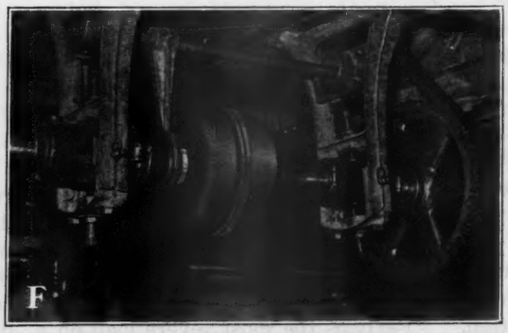
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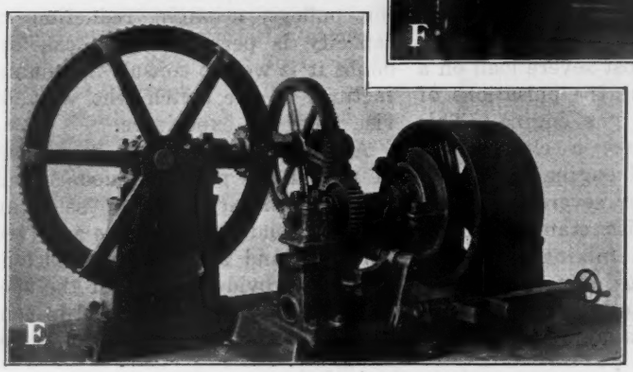
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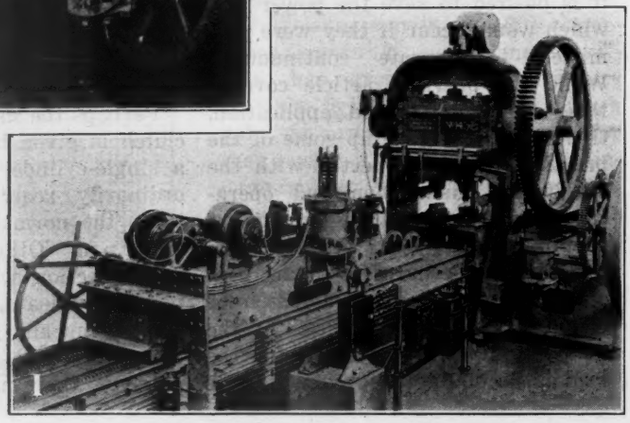
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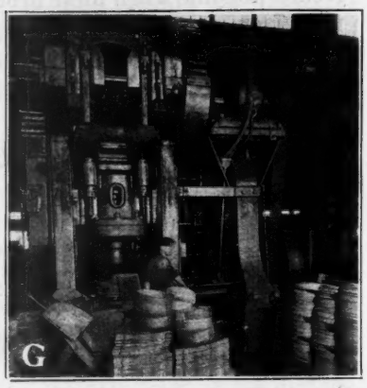
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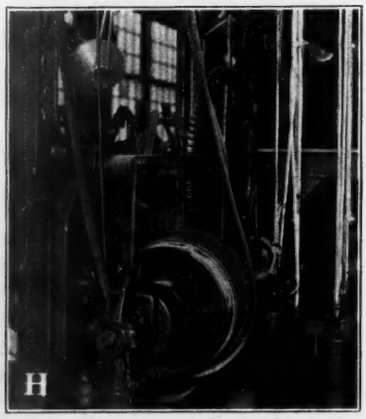
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A—Here clutches enable the entire lineshaft as well as individual machines to be cut out when not required without shutting down the whole plant or continuing to operate with heavy friction losses.

B—Foot-operated clutch and brake.

C—A guarded clutch on a heavy machine.

D—This large press is tripped through a clutch attached to the flywheel.

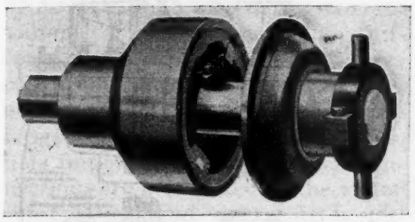
E—A clutch installation in the driving mechanism of a paper machine.

F—Totally-enclosed, cut-off coupling on a lineshaft driven by silent chains.

G—Many large presses are set in motion through a friction or jaw clutch.

H—A clutch with lever trip for starting and stopping.

I—Here a 10-in. magnetic clutch is used in controlling one of the automatic motions of a spacing machine.



An example of the expanding-ring type of friction clutch.

This clutch consists of a combined clutch casing and sleeve which rides free upon the shaft and upon which the pulley, gear, sprocket, or similar member is fixed. Within the casing is an expanded ring, which is keyed to the shaft, and makes frictional contact with the inner surface of the casing when expanded by two floating steel fingers and floating pins located within the ring. An oil and dust-tight cover encloses the clutch mechanism.

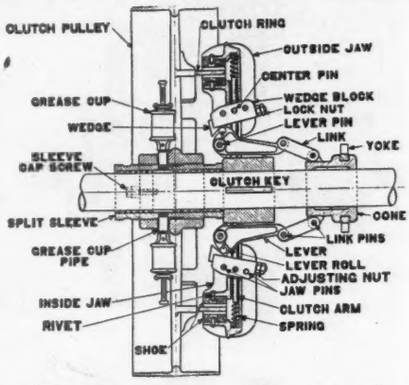
quired to start heavy masses from a state of rest; for instance, heavy flywheels, armatures and centrifugal separators. Also, large clutches must be provided to meet the conditions incidental to the operation of pumps, air compressors, and machines that are often started while under load, as saw mills, rolling mills, crushing plants and other similar machines. Because of the increased friction and heat, it is also advisable to use clutches of increased capacity when conditions require high speed or frequent engagement and disengagement. Perhaps the best general rule to apply in the selection of a clutch is to use one with the full rated capacity of the pulley to which it is connected at the rated speed, or of a double belt of the proper width for the pulley. Another reason for installing a clutch of the full rated capacity of the pulley which it may be called upon to drive, is that manufacturers frequently under-specify the power required to drive their machines and also when connected to a group of lineshafting, in particular, additional or larger machines may be added at any time. For this reason, for a lineshaft cutoff coupling it is always well to install a coupling of the full capacity of the lineshaft. It is also advisable when figuring the horsepower rating of a friction clutch or coupling, to take into consideration the effect of suddenly applied loads and the running speed, rather than simply the power transmitted through the clutch when engaged. Obviously, there is much more slippage when engaging a clutch on a fast-running shaft than on a slow-speed shaft. This, of course, affects the life of the friction surfaces.

To obtain the proper bearing surface on the shaft and to eliminate a twisting torque it is always advisable to see that the bearing or sleeve is at least 1¼ times the width of the connected pulley.

In ordering clutches, clutch pulleys and cutoff couplings, or asking for an estimate, it is well to give the following information:

(*a*) Diameter of pulley; (*b*) width of belt (width of belt is necessary in order that proper allowance may be made in the sleeve length for bearing surface); (*c*) diameter of shaft; (*d*) solid or split (use split only when absolutely necessary); (*e*) revolutions of shaft per minute; (*f*) horsepower required at starting and thereafter; (*g*) character of service; (*h*) if for gas engine service, state number of cylinders; (*i*) if space on shaft is limited, give maximum allowable space; (*j*) key sizes.

Whenever possible it is advisable that the clutch mechanism be mounted upon the driven shaft in order that adjustments may be made without shutting down the entire line. Ordinarily, ¼ in., or on a large shaft a little more, should be allowed between the ends of the two shafts with cutoff couplings. In some types the end of one shaft extends into the hub of the other. When erecting friction clutches or couplings one of the first steps is to see that the shaft is properly aligned and round and smooth where the sleeve runs. The coupling or clutch should be thoroughly cleaned out and the bore of the sleeve and the shaft lubricated before slipping the sleeve into position. Next see that the sleeve is a free running fit on the shaft, as not all shafts are of exact standard gage. Before ordering the coupling, measure to see if the shaft is off gage; if so have the coupling bored to gage. Before the

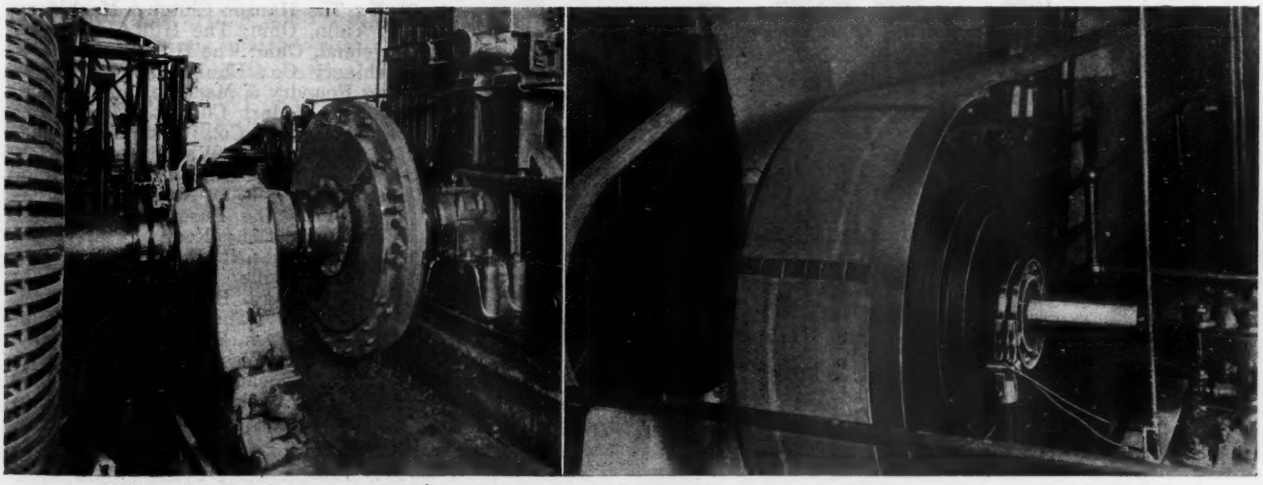


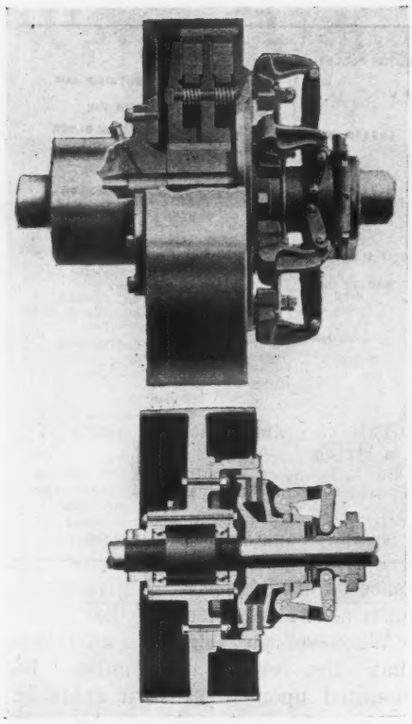
This diagram names the parts of a clutch.

In ordering a repair part or extra parts for replacement the manufacturer must know the type, style, or model, size, any special dimensions, and if possible the original order number.

Magnetic cutoff coupling and clutch pulley installations.

The installation below shows a 30-in. magnetic clutch fastened to a pulley on an engine-driven, paper-making machine. The engine and clutch are installed in the basement of the paper mill and the paper machine on the first floor. The operator starts and stops the paper machine by means of a switch located conveniently. The installation at the left shows a magnetic cutoff clutch coupling connecting a synchronous motor to a mill.



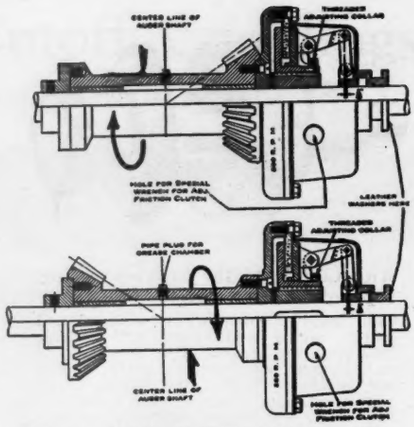


Two disk-type friction clutch couplings.
In one of these clutches, the disengagement is through the aid of the toggles while in the other a spring assists in forcing the jaws apart.

clutch is operated it must be thoroughly lubricated by forcing in as much lubricant as possible. In some cases it may be necessary to fill the grease cups two or three times before all spaces and passages are filled. The most important step after the clutch is in service is to see that it is regularly and thoroughly lubricated. Clutches used frequently should receive daily attention unless they are of the ball-bearing type.

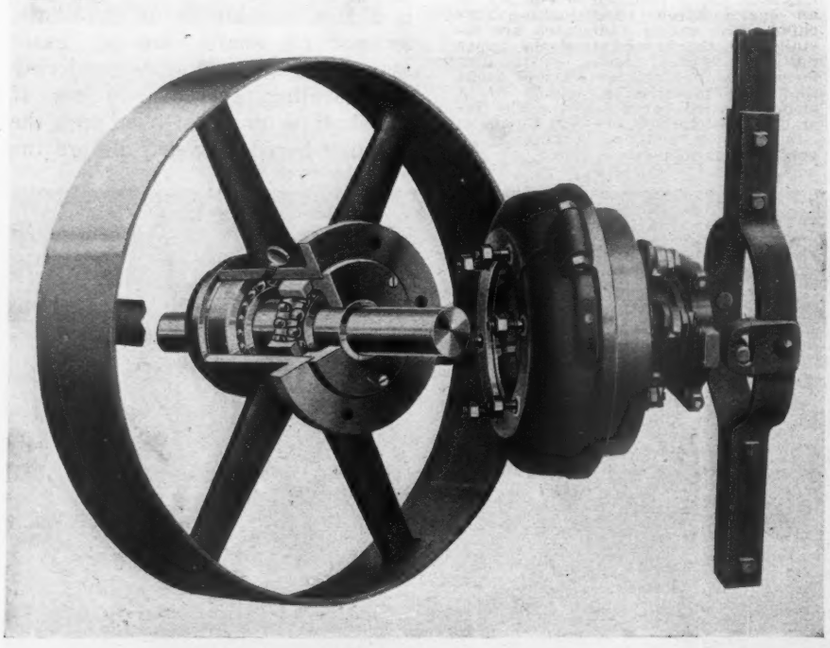
After a friction clutch or coupling has been in operation it is sometimes necessary to make slight adjustments to compensate for the wear of the friction surfaces. In doing this care should be exercised to see that the different arms of the clutch are tightened evenly or else they will be thrown out of adjustment and not give even pressure, or they rub at some point when disconnected. With some types of clutches all adjustments are made at once, so that all are made evenly. A friction surface will wear rapidly if permitted to rub while disengaged. If the jaws rub on the friction surface, either the springs do not force the jaws apart sufficiently or else the clutch is not properly adjusted.

One of the important considerations in installing friction clutch cutoff couplings is to see that the shafting is properly in line before installing the coupling. It is always well to remember that even though properly aligned when first installed, shafting does not always remain that way. Shifting loads or machines on floors above often may change the alignment of a shafting. Frequent inspections of shafting for alignment not only reduce the friction load but also more than pay for themselves in the savings on bearings, friction clutches, and other similar equipment. Two of the more common causes of excessive wear in friction clutches and couplings are misalignment of shafting and neglect of lubrication. If the shaft is aligned properly, and the coupling lubricated and of sufficient capacity there should be but little opportunity for trouble.



One method of getting the proper direction of rotation.
In many machines, it is absolutely necessary that the shafts revolve in a certain direction. In this pair of clutches, the spur gear is reversed, as shown in the two sketches. This is a single-disk friction clutch, where the pressure is applied equally on both sides of the disk.

Cut-away view of a ball-bearing friction clutch pulley.
One of the common causes of difficulty with loose pulleys and clutch pulleys lies in the liability to neglect the lubrication. For high-speed work as well as clutches and pulleys which are difficult of access, and so are liable to be neglected, ball bearings are recommended because of the less frequent necessity of lubrication.



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INASMUCH AS alternating current motors can be reconnected for different voltages by taking advantage of various series and parallel connections, and of star and delta arrangements in three-phase designs, it is important to know which connections are best suited to the stator construction and operating conditions. When rewinding a stator there are even more combinations that can be used by varying the number of turns per coil and the coil pitch. In this article Mr. Roe presents handy tables which show the changes that can be made.

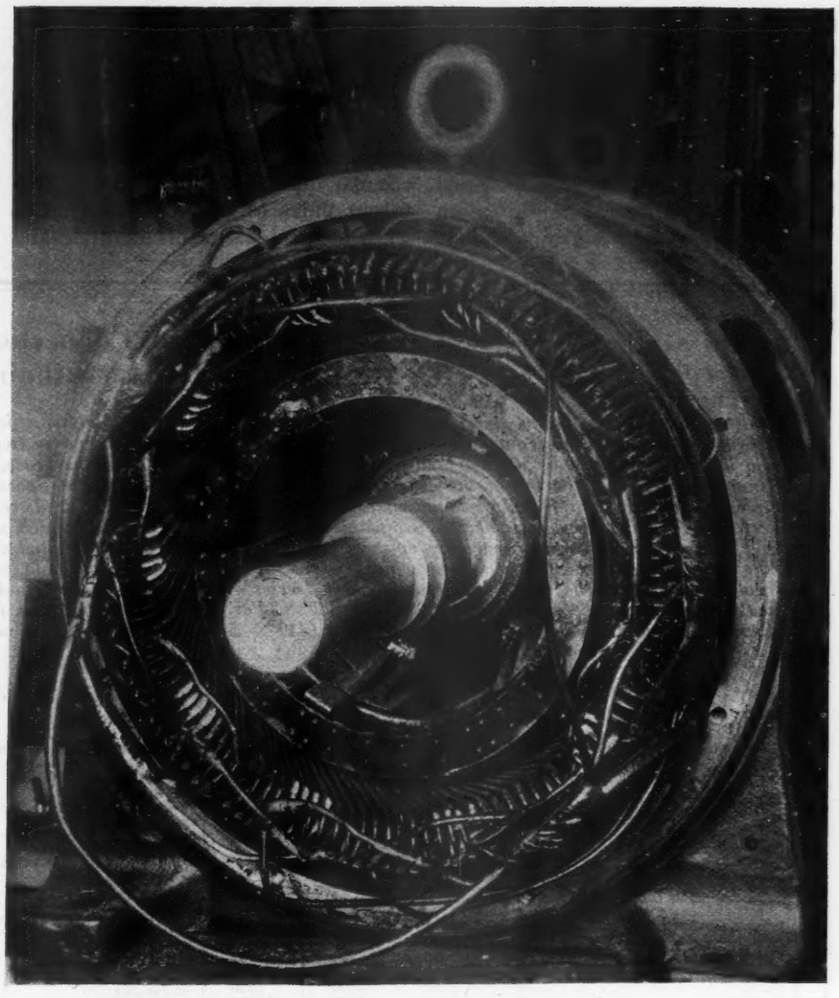
Some Handy Tables For Use in Making

Voltage Changes on A. C. Motors

By Reconnecting, or by Changing Coil Pitch and Chord Factor and by Rewinding the Coils

By A. C. ROE

Repair Superintendent, Detroit Service Department, Westinghouse Electric & Manufacturing Co.



After examining the existing connections the next step is to decide whether the stator should be reconnected or rewound.

QUITE often it is desired to reconnect the windings of an induction motor to operate on different line voltages or, when rewinding a stator, some bad feature in the coils or connections may be eliminated by changing the type of connections, the coil pitch, the turns per coil, and so on. It is the purpose of this article, therefore, to discuss the various changes that affect the voltage and to outline the possibilities of removing bad features as well as the effects of over- and undervoltage on the operation of the motor.

To begin with, we can consider the stator winding of an induction motor as a generator. Then any change made that tends to increase or decrease the turns in series per phase will also increase or decrease the voltage in the same proportion and in the same direction as that in which the turns are changed. In applying this rule in practice we must remember, also, that when the turns per phase are changed more than 10 per cent, a corresponding change in the cross section of the conductor should be made in the same proportion, but in the opposite direction.

One important rule when rewinding or reconnecting a motor is to keep the voltage per turn the same as it was originally, if the horsepower, speed, frequency and number of phases are to remain the same. Also be sure that the new arrangement of the winding is within 5 per cent of the proper line voltage, if possible, and in any case do not exceed 10 per cent either way. These figures can sometimes be exceeded for intermittent duty and temporary jobs and will no doubt work satisfactorily, but for a good permanent job, keep within these limits. This can usually be done by changing the type of connection, the turns per coil and the chord factor. Sometimes, however, it is not possible to keep the voltage the same. In such a case the effect of undervoltage or overvoltage must be considered.

The most common voltage changes are from 220 volts to 110 volts, 220 to 440, 440 to 110, or *vice versa* in each case. On some stators this can be accomplished by reconnecting from series to two-parallel, etc., depending upon the number of poles, coils per phase and the original connection. When the original connection is a series connection, it is obvious that the voltage can not be increased by reconnecting. In this case it is necessary to rewind the stator with the turns per coil increased in the same proportion as the voltage is to be increased. At the same time the size of wire (circ. mil) must be decreased in the same proportion.

Do not attempt to raise the voltage of 110-, 220-, 440-, and 550-volt motors above 550 volts without rewinding, as the insulation to ground and between phases on motors of this voltage range is not sufficient to stand continuous operation at higher voltage. It may be possible to jug-

gle the connections to get the desired voltage but this should not be done.

Another point to remember when making a voltage change is: Do not attempt to parallel the coils in any one pole-phase-group. This means that on first sight it might seem that we cannot split a group in half and parallel the halves with each other. Each group could be split into two sections of two coils and these two sections put in parallel. However, if this were done circulating currents would be set up, due to angular displacement of the different pairs of coils. If the motor were connected in this manner and put on the line, in about ten minutes it would be found that there were two hot coils, then two cool coils, alternately, throughout the winding. Therefore, when reconnecting do not split the groups but use them as units.

To help determine what connection to use to get the required volt-

Table I—All Practical Connections for 4-to 24-Pole, 2-Phase Windings

The first vertical column gives the original connection. Each figure on the same horizontal line with any original connection is the multiple to be used to find the line voltage for the connection listed at the top of the different columns. For example, assume that a 440-volt, two-phase, four-pole, series-connected, motor is to be reconnected two-parallel and it is desired to know the resulting operating voltage. On consulting the table for a four-pole, two-phase winding, look in the first column and find the line in which the word "series" is located. Then in the column marked "two-parallel" (2-Par.) the figure .5 is found which, multiplied by 440 volts (440 × .5) equals 220 volts, which is the operating voltage when the winding is changed to two-parallel.

As another case, assume that it is desired to change the same motor to operate on 110 volts. What connection would give the desired result? In this case divide 110 by 440 (110 ÷ 440) which gives .25. Then look along the horizontal line under original connection column marked "series" of the table for four-pole, two-phase motors and locate the figure .25 which will be found under four-parallel (4-Par.) connection. This indicates that the four-parallel connection will give the required operating voltage of 110, since 440 × .25 equals 110.

Four-Pole, Two Phase

Original Connection	Series	2-Par	4-Par.
Series	1.00	.50	.25
2-Parallel	2.00	1.00	.50
4-Parallel	4.00	2.00	1.00

Six-Pole, Two-Phase

Original Connection	Series	2-Par.	3-Par.	6-Par.
Series	1.00	.50	.333	.167
2-Parallel	2.00	1.00	.667	.334
3-Parallel	3.00	1.50	1.00	.500
6-Parallel	6.00	3.00	2.00	1.000

Eight-Pole, Two-Phase

Original Connection	Series	2-Par.	4-Par.	8-Par.
Series	1.00	.50	.25	.125
2-Parallel	2.00	1.00	.50	.250
4-Parallel	4.00	2.00	1.00	.50
8-Parallel	8.00	4.00	2.00	1.00

Ten-Pole, Two-Phase

Original Connection	Series	2-Par.	5-Par.	10-Par.
Series	1.00	.50	.20	.1
2-Parallel	2.00	1.00	.40	.2
5-Parallel	5.00	2.50	1.00	.5
10-Parallel	10.00	5.00	2.00	1.0

Twelve-Pole, Two-Phase

Original Connection	Series	2-Par.	3-Par.	4-Par.	6-Par	12-Par.
Series	1.00	.500	.33	.25	.167	.083
2-Parallel	2.00	1.00	.667	.50	33	.167
3-Parallel	3.00	1.50	1.00	.75	.50	.25
4-Parallel	4.00	2.00	1.33	1.00	.66	.334
6-Parallel	6.00	3.00	2.00	1.50	1.00	.50
12-Parallel	12.00	6.00	4.00	3.00	2.00	1.00

Fourteen-Pole, Two-Phase

Original Connection	Series	2-Par.	7-Par.	14-Par.
Series	1.00	.50	.143	.071
2-Parallel	2.00	1.00	.286	.143
7-Parallel	7.00	3.50	1.00	.50
14-Parallel	14.00	7.00	2.00	1.00

Sixteen-Pole, Two-Phase

Original Connection	Series	2-Par.	4-Par.	8-Par.	16-Par.
Series	1.00	.50	.25	.125	.0625
2-Parallel	2.00	1.00	.50	.25	.125
4-Parallel	4.00	2.00	1.00	.50	.25
8-Parallel	8.00	4.00	2.00	1.00	.50
16-Parallel	16.00	8.00	4.00	2.00	1.00

Eighteen-Pole, Two-Phase

Original Connection	Series	2-Par.	3-Par.	6-Par.	9-Par.	18-Par.
Series	1.00	.50	.33	.167	.11	.056
2-Parallel	2.00	1.00	.66	33	.22	.11
3-Parallel	3.00	1.50	1.00	.50	.33	.167
6-Parallel	6.00	3.00	2.00	1.00	.66	.33
9-Parallel	9.00	4.50	3.00	1.50	1.00	.50
18-Parallel	18.00	9.00	6.00	3.00	2.00	1.00

Twenty-Pole, Two-Phase

Original Connection	Series	2-Par.	4-Par.	5-Par.	10-Par.	20-Par.
Series	1.00	.50	.25	.20	.10	.05
2-Parallel	2.00	1.00	.50	.40	.20	.10
4-Parallel	4.00	2.00	1.00	.80	.40	.20
5-Parallel	5.00	2.50	1.25	1.00	.50	.25
10-Parallel	10.00	5.00	2.50	2.00	1.00	.50
20-Parallel	20.00	10.00	5.00	4.00	2.00	1.00

Twenty-two-Pole, Two-Phase

Original Connection	Series	2-Par	11-Par.	22-Par.
Series	1.00	.50	.091	.046
2-Parallel	2.00	1.00	.182	.091
11-Parallel	11.00	5.50	1.00	.500
22-Parallel	22.00	11.00	2.00	1.000

Twenty-four-Pole, Two-Phase

Original Connection	Series	2-Par.	3-Par.	4-Par.	6-Par.	8-Par.	12-Par.	24-Par.
Series	1.00	.50	.33	.25	.165	.125	.083	.0415
2-Parallel	2.00	1.00	.66	.50	.33	.25	.167	.083
3-Parallel	3.00	1.50	1.00	.75	.50	.375	.25	.125
4-Parallel	4.00	2.00	1.33	1.00	.66	.50	.33	.165
6-Parallel	6.00	3.00	2.00	1.50	1.00	.75	.50	.25
8-Parallel	8.00	4.00	2.66	2.00	1.33	1.00	.66	.33
12-Parallel	12.00	6.00	4.00	3.00	2.00	1.50	1.00	.50
24-Parallel	24.00	12.00	8.00	6.00	4.00	3.00	2.00	1.00

age or what the line voltage should be with any other possible connection, Tables I to VII have been developed. There are two tables for each number of poles, one for two-phase and one for three-phase. Each table gives all the possible connections for each of the number of poles to which it applies. The first vertical column in a table gives the original connection; then each figure on the same horizontal line with any original connection is the multiple to be used to find what the line voltage should be with the connection listed in the top line. Assume a 440-volt, two-phase, four-pole motor series connected. On consulting Table I we look in the first column and find the horizontal line in which the word *Series* is located. Then the first figure is 1 and above this figure is the word *Series* which indicates that no change is made. But the second figure is .5 which indicates that with two-parallel connection the motor would have to operate with $440 \times .5$ equals 220 volts. Again under *4-Parallel* appears the figure .25. This signifies that with a four-parallel connection the line voltage would have to be $440 \times .25$ equals 110 volts. Another use of the table is to find the required connection for a certain voltage. Assuming the same motor as before, a 440-volt series connection, suppose it is desired to change the voltage to 110. What connection would give the desired results? To find the factor divide the required voltage by the original voltage, or $110 \div 440 = .25$. In doing this be sure about the position of the decimal point. Then looking along the original connection (series) horizontal line we locate .25 under *4-Parallel* which connection will give the required voltage.

For three-phase stators the tables are found more useful, as there are two types of connection possible: namely, star and delta. This gives a greater range of combinations. In any star-connected machine the voltage per phase is equal to line voltage divided by 1.73. In other words if a series, star-connected motor is operating on a 220-volt three-phase line, the volts per phase will be 127. This motor could be connected series-delta and operated on 127 volts which is approximately 58 per cent of the series-star line voltage. Conversely, a 110-volt, series-delta-connected motor could be connected series-star and operated on 1.73×110 equals 190 volts. A few actual examples will be given to show the use of the tables.

Suppose we have a three-phase, six-pole 2,300-volt motor that is connected two-parallel star (2-Par. Y) and we want to reconnect it for 440 volts. Then $440 \div 2{,}300$ equals .1913. Consulting Table II and the *2-Parallel Star* horizontal line, we find the factor .193 under *6-Parallel Delta*. Then if we connect the motor six-parallel delta it would require a line voltage of $2{,}300 \times .193$ or 443.9 volts, which is 3.9 volts over but is satisfactory.

In another case assume that we have a 110-volt, three-phase, twelve-pole motor, six-parallel connected and want to reconnect it for 550 volts. Then the factor required is $550 \div 110$ equals 5.0. Looking in Table III on the *6-Parallel Delta* line, we find the factor 5.2 under *2-Parallel Star*. If, we, accordingly, reconnect this motor for two-parallel star, the line voltage will have to be 110×5.2 equals 572 volts, or 22 volts over 550, which is satisfactory, as standard motors are listed to operate on 10 per cent over- or under-voltage. Another example is a 24-pole, three-phase, 4,600-volt, series-star-connected motor which it is desired to reconnect for 110 volts. Then $110 \div 4{,}600$ equals .024.

Table II—All Practical Connections for 2-to 8-Pole, 3-Phase Windings

See heading of Table I for instructions on using these tables.

Two-Pole, Three-Phase

Original Connection	Series Star	Series Delta	2-Par. Star	2-Par. Delta
Series—Star	1.00	.58	.50	.29
Series—Delta	1.73	1.00	.865	.50
2-Parallel—Star	2.00	1.16	1.00	.58
2-Parallel—Delta	3.46	2.00	1.73	1.00

Four-Pole, Three-Phase

Original Connection	Series		2-Parallel		4-Parallel	
	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.25	.145
Series—Delta	1.73	1.00	.865	.50	.432	.25
2-Parallel—Star	2.00	1.16	1.00	.58	.50	.29
2-Parallel—Delta	3.46	2.00	1.73	1.00	.865	.50
4-Parallel—Star	4.00	2.32	2.00	1.16	1.00	.58
4-Parallel—Delta	6.92	4.00	3.46	2.00	1.73	1.00

Six-Pole, Three-Phase

Original Connection	Series		2-Parallel		3-Parallel		6-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.500	.29	.333	.193	.167	.096
Series—Delta	1.73	1.00	.865	.50	.576	.333	.289	.167
2-Parallel—Star	2.00	1.16	1.00	.58	.666	.386	.334	.193
2-Parallel Delta	3.46	2.00	1.73	1.00	1.152	.666	.578	.334
3-Parallel—Star	3.00	1.73	1.50	.865	1.00	.577	.500	.288
3-Parallel Delta	5.19	3.00	2.60	1.50	1.73	1.000	.865	.500
6-Parallel Star	6.00	3.46	3.00	1.73	2.00	1.15	1.00	.577
6-Parallel Delta	10.38	6.00	5.19	3.00	3.46	2.00	1.73	1.000

Eight-Pole, Three-Phase

Original Connection	Series		2-Parallel		4-Parallel		8-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.25	.145	.125	.0725
Series—Delta	1.73	1.00	.865	.50	.432	.25	.216	.125
2-Parallel—Star	2.00	1.16	1.00	.58	.50	.29	.25	.145
2-Parallel—Delta	3.46	2.00	1.73	1.00	.865	.50	.432	.25
4-Parallel—Star	4.00	2.32	2.00	1.16	1.00	.58	.50	.29
4-Parallel—Delta	6.92	4.00	3.46	2.00	1.73	1.00	.865	.50
8-Parallel—Star	8.00	4.64	4.00	2.32	2.00	1.16	1.00	.58
8-Parallel Delta	13.84	8.00	6.92	4.00	3.46	2.00	1.73	1.00

It can be seen that the tables will be of considerable help in solving many reconnection problems. The connecting diagrams published in the March, April, May and June issues of INDUSTRIAL ENGINEER can be used with these tables.

To illustrate how changing the type of connection can be done in some cases to speed up a rewinding job, it may be well to mention a recent case which came under the writer's supervision. We had a 96-slot, three-phase stator connected two-parallel star. This was to be rewound to perform the same duties as before. There were ninety-six coils, diamond-pulled, of fourteen turns of one No. 13 square wire. The wires in the coil were laid two wide by seven deep which is called a "cross-over" coil. Each cross-over had to be taped which meant that each coil would require considerable time to make. But it was found that this cross-over could be eliminated by using a plain coil and changing the motor connections. Accordingly the coils were made up of seven turns of two No. 13 square wires in parallel (2 by 7) thus cutting the turns per coil in half and eliminating the cross-over. This type of coil can be wound in one-third the time required for a cross-over coil. Changing the turns to one-half also increased the cross section of copper 100 per cent and this would indicate that the motor should be operated on half the original voltage. However, the connections were changed from two-parallel star to series-star enabling the motor to run on original voltage.

It is combined changes like this one that enable a great deal of time to be saved in repair work. Furthermore, the time saved is not the only benefit derived from eliminating a cross-over coil. Another important feature is that with the average help in most repair shops there is more chance for short circuits in cross-over coils. The reason for this is illustrated in Fig. 1. At

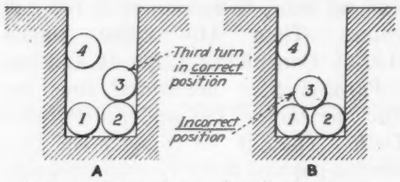


Fig. 1—How short circuits in cross-over coils frequently occur.

At *A* is shown the first three turns wound correctly in place. The first turn is at the left, the second on the right and the third is on top of the second. At this point trouble starts, as the third turn has a tendency to slip down into the space formed on top of the two round wires, as shown in diagram *B*. When the fourth turn is laid in and an attempt made to flatten out the second layer by pounding with a drift and mallet, there is not enough space between the third turn and the side of the shuttle for the fourth turn. This pounding tends to crush the cotton covering on wires 3 and 4 and may cause a dead short circuit.

A are shown the first three turns wound correctly in place. The first turn is at the left, the second on the right, and the third is on top of the second. It is at this point that trouble starts, as the third turn has a tendency to slip down into the space formed on top of the two round wires, as in drawing *B*. When the fourth turn is laid in and an attempt made to flatten out the second layer by pounding with a fiber drift and mallet, there is not enough space between the third turn and the side of the shuttle for the fourth turn.

Pounding tends to crush the cotton covering on wires 3 and 4. If they are pounded hard enough the insulation will be cut and a dead short will result. Unless each coil is carefully inspected, this defect will not be noticed until the stator is wound and given a balance and run test which means time lost in removing the faulty coils.

There is another item that can be changed to vary the voltage when rewinding. This is the chord factor, which may be changed by changing the coil pitch. The chord factor depends entirely on the pitch, the number of poles, and it will be the same for any number of phases.

The chord factor is equal to the sin of one-half the electrical angle included between the two halves of one coil. In practice the chord factor is found as follows: First divide

Table III—All Practical Connections for 10-and 12-Pole, 3-Phase Windings

See heading of Table I for instructions on using these tables

Ten-Pole, Three-Phase

Original Connection	Series		2-Parallel		5-Parallel		10-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.20	.116	.10	.058
Series—Delta	1.73	1.00	.865	.50	.346	.20	.173	.10
2-Parallel—Star	2.00	1.16	1.00	.58	.40	.232	.20	.116
2-Parallel—Delta	3.46	2.00	1.73	1.00	.692	.40	.346	.20
5-Parallel—Star	5.00	2.90	2.50	1.45	1.00	.58	.50	.29
5-Parallel—Delta	8.65	5.00	4.32	2.50	1.73	1.00	.865	.50
10-Parallel—Star	10.00	5.80	5.00	2.90	2.00	1.16	1.00	.58
10-Parallel—Delta	17.30	10.00	8.65	5.00	3.46	2.00	1.73	1.00

Twelve-Pole, Three-Phase

Original Connection	Series		2-Parallel		3-Parallel		4-Parallel		6-Parallel		12-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.33	.193	.25	.145	.167	.096	.084	.048
Series—Delta	1.73	1.00	.865	.50	.576	.333	.432	.25	.288	.167	.144	.084
2-Parallel—Star	2.00	1.16	1.00	.58	.66	.386	.50	.29	.334	.193	.167	.097
2-Parallel—Delta	3.46	2.00	1.73	1.00	1.15	.66	.865	.50	.578	.334	.288	.167
3-Parallel—Star	3.00	1.73	1.50	.87	1.00	.58	.75	.435	.50	.29	.25	.145
3-Parallel—Delta	5.19	3.00	2.60	1.50	1.73	1.00	1.30	.75	.865	.50	.432	.25
4-Parallel—Star	4.00	2.32	2.00	1.16	1.33	.772	1.00	.58	.66	.386	.33	.193
4-Parallel—Delta	6.92	4.00	3.46	2.00	2.30	1.33	1.73	1.00	1.15	.66	.577	.33
6-Parallel—Star	6.00	3.46	3.00	1.73	2.00	1.16	1.50	.87	1.00	.58	.50	.29
6-Parallel—Delta	10.38	6.00	5.19	3.00	3.46	2.00	2.60	1.50	1.73	1.00	.865	.50
12-Parallel—Star	12.00	6.92	6.00	3.46	4.00	2.30	3.00	1.73	2.00	1.15	1.00	.57
12-Parallel—Delta	20.76	12.00	10.38	6.00	6.92	4.00	5.19	3.00	3.46	2.00	1.73	1.00

the total number of *slots (N)* by the number of poles *(P)*. This gives the number of slots per pole. Then take the coil pitch *(C)* and divide it by the number of slots per pole. This will give the pitch as a fraction of full pitch. Multiply 90 deg. by this fraction and the result will be a certain number of degrees. Then the sin of this angle equals the chord factor. These steps may be reduced to one formula which is:

Chord factor = sin C ÷ N/P × 90 degrees.

(Note: First divide *N* by *P*. Then divide *C* by this answer and multiply by 90.)

In this formula: *N* = Total number of slots; *P* = Number of poles; *C* = Coil pitch.

The sin may be found from Table VIII in this article or from other tables in handbooks.

For example, assume a 96-slot, four-pole stator, with coil pitch of 1-and-20, or 19 slots. The chord factor equals sin [19 ÷ (96 ÷ 4)] × 90 = (19 ÷ 24) × 90 = .79125 × 90 = sin 71.21 deg. In many tables the fraction of a degree is expressed in *minutes* and consequently the .21 of the 71.21 must be reduced to minutes. There are 60 min. per 1 deg.; therefore 60 × .21 = 12 min.

The sin of this angle 71.21 deg. (or 70° 12′) equals .9466, which equals the chord factor. If the voltage of the motor with full pitch was 100 volts, it would be 94.66 volts with the above-mentioned pitch of 1-and-20 (19 slots).

Suppose that in the example given above it was found that eighteen

Table IV—All Practical Connections for 14-to 20-Pole, 3 Phase Windings

See heading of Table I for instructions on using these tables

Fourteen-Pole, Three-Phase

Original Connection	Series		2-Parallel		7-Parallel		14-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.143	.083	.071	.042
Series—Delta	1.73	1.00	.865	.50	.247	.143	.124	.071
2-Parallel—Star	2.00	1.16	1.00	.58	.286	.166	.143	.083
2-Parallel—Delta	3.46	2.00	1.73	1.00	.494	.286	.247	.143
7-Parallel—Star	7.00	4.06	3.50	2.03	1.00	.58	.50	.29
7-Parallel—Delta	12.11	7.00	6.06	3.50	1.73	1.00	.865	.50
14-Parallel—Star	14.00	8.12	7.00	4.06	2.00	1.16	1.00	.58
14-Parallel—Delta	24.22	14.00	12.11	7.00	3.46	2.00	1.73	1.00

Sixteen-Pole, Three-Phase

Original Connection	Series		2-Parallel		4-Parallel		8-Parallel		16-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.25	.145	.125	.073	.063	.037
Series—Delta	1.73	1.00	.865	.50	.432	.25	.216	.125	.108	.063
2-Parallel—Star	2.00	1.16	1.00	.58	.50	.29	.25	.145	.125	.073
2-Parallel—Delta	3.46	2.00	1.73	1.00	.865	.50	.432	.25	.216	.125
4-Parallel—Star	4.00	2.32	2.00	1.16	1.00	.58	.50	.29	.25	.145
4-Parallel—Delta	6.92	4.00	3.46	2.00	1.73	1.00	.865	.50	.432	.25
8-Parallel—Star	8.00	4.64	4.00	2.32	2.00	1.16	1.00	.58	.50	.29
8-Parallel—Delta	13.84	8.00	6.92	4.00	3.46	2.00	1.73	1.00	.865	.50
16-Parallel—Star	16.00	9.28	8.00	4.64	4.00	2.32	2.00	1.16	1.00	.58
16-Parallel—Delta	27.68	16.00	13.84	8.00	6.92	4.00	3.46	2.00	1.73	1.00

Eighteen-Pole, Three-Phase

Original Connection	Series		2-Parallel		3-Parallel		6-Parallel		9-Parallel		18-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.33	.193	.167	.097	.11	.064	.055	.032
Series—Delta	1.73	1.00	.865	.50	.577	.33	.289	.167	.19	.11	.09	.055
2-Parallel—Star	2.00	1.16	1.00	.58	.66	.386	.33	.193	.22	.128	.11	.064
2-Parallel—Delta	3.46	2.00	1.73	1.00	1.15	.66	.577	.33	.38	.22	.18	.11
3-Parallel—Star	3.00	1.73	1.50	.86	1.00	.58	.50	.29	.33	.193	.167	.097
3-Parallel—Delta	5.19	3.00	2.59	1.50	1.73	1.00	.865	.50	.57	.33	.28	.167
6-Parallel—Star	6.00	3.46	3.00	1.73	2.00	1.15	1.00	.58	.66	.383	.33	.191
6-Parallel—Delta	10.38	6.00	5.19	3.00	3.46	2.00	1.73	1.00	1.15	.66	.57	.33
9-Parallel—Star	9.00	5.19	4.5	2.59	3.00	1.73	1.50	.87	1.00	.57	.50	.285
9-Parallel—Delta	15.57	9.00	7.78	4.50	5.19	3.00	2.59	1.50	1.73	1.00	.86	.50
18-Parallel—Star	18.00	10.38	9.00	5.19	6.00	3.46	3.00	1.73	2.00	1.15	1.00	.575
18-Parallel—Delta	31.14	18.00	15.57	9.00	10.38	6.00	5.19	3.00	3.46	2.00	1.73	1.00

Twenty-Pole, Three-Phase

Original Connection	Series		2-Parallel		4-Parallel		5-Parallel		10-Parallel		20-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.25	.145	.20	.116	.10	.058	.05	.029
Series—Delta	1.73	1.00	.865	.50	.432	.25	.346	.20	.173	1.00	.087	.05
2-Parallel—Star	2.00	1.16	.10	.58	.50	.29	.40	.232	.20	.116	.10	.058
2-Parallel—Delta	3.46	2.00	1.73	1.00	.865	.50	.692	.40	.346	.20	.173	.10
4-Parallel—Star	4.00	2.32	2.00	1.16	1.00	.58	.80	.464	.40	.232	.20	.116
4-Parallel—Delta	6.92	4.00	3.46	2.00	1.73	1.00	1.38	.80	.69	.40	.345	.20
5-Parallel—Star	5.00	2.90	2.50	1.45	1.25	.725	1.00	.58	.50	.29	.25	.145
5-Parallel—Delta	8.65	5.00	4.32	2.50	2.16	1.25	1.73	1.00	.865	.50	.432	.25
10-Parallel—Star	10.00	5.80	5.00	2.90	2.50	1.45	2.00	1.16	1.00	.58	.50	.29
10-Parallel—Delta	17.30	10.00	8.65	5.00	4.32	2.50	3.46	2.00	1.73	1.00	.865	.50
20-Parallel—Star	20.00	11.60	10.00	5.80	5.00	2.90	4.00	2.32	2.00	1.16	1.00	.58
20-Parallel—Delta	34.60	20.00	17.30	10.00	8.65	5.00	6.92	4.00	3.46	2.00	1.73	1.00

turns per coil would be correct for a line voltage of 440 with a full pitch coil, 1 and 25. However, the coil ends with this pitch projected out beyond the iron too far and interfered with the end bells and to wind properly the coil had to be shortened to a pitch of 1 and 20. Now shortening the coil pitch decreases the activity of the coil sides and the coil will develop less voltage. This is easily understood because we know that with full pitch both halves of the coil are in maximum fields at the same instant, hence the coil is developing its maximum voltage; but when the pitch is shortened, one side of the coil will be in a weaker field and the coil will develop a lower voltage. So changing the coil pitch has practically the same effect on the voltage as changing the turns per coil; decreasing the coil pitch decreases the voltage and *vice versa*. The amount of change is indicated by the chord factor. In the above case the chord factor is .9466 for coil pitch 1 and 20; then the line voltage would be $440 \times .9466$, equals 416.40 volts. To bring the voltage back to 440, the turns would have to be increased 5.6 per cent, or 18×1.056, equals 19.006 turns. In this case dropping five slots has the same effect as dropping one turn per coil.

A much simpler tabulation of chord factors is shown in Table V. In this table the first column gives the pitch in the percentage of full pitch. The second column gives the chord factor corresponding to this percentage of pitch. As an example of using this table suppose we have a six-pole, 120-slot stator with a pitch of 1 and 19 or 18 slots. Full pitch equals $120 \div 6$ equals 20 slots. The present pitch is $18 \div 20$ or 90 per cent of full pitch. From the table we find that for 90 per cent pitch the chord factor is 0.988.

Table V—Chord Factors for Different Coil Pitches

Per Cent Pitch	Chord Factor	Per Cent Pitch	Chord Factor
100	1.00000	75	.92388
99	.99988	74	.91775
98	.99951	73	.91140
97	.99889	72	.90483
96	.99803	71	.89803
95	.99692	70	.89101
94	.99556	69	.88376
93	.99396	68	.87631
92	.99211	67	.86863
91	.99002	66	.86074
90	.98769	65	.85264
89	.98511	64	.84433
88	.98229	63	.83581
87	.97922	62	.82708
86	.97592	61	.81815
85	.97237	60	.80902
84	.96858	59	.79968
83	.96456	58	.79015
82	.96029	57	.78043
81	.95579	56	.77051
80	.95106	55	.76041
79	.94608	54	.75011
78	.94088	53	.73963
77	.93544	52	.72917
76	.92978	51	.71813

Many a time when rewinding a stator the coils are accidentally made up a bit short, thus making a tight winding job. Another time the end room on the original winding may have been scant, so that if the same pitch is used when rewinding the job will again be difficult.

In either case dropping one or two slots may ease things up and make a quicker and safer job, but the question is, how will this affect the machine? As already stated, reducing the voltage of a generator while operating on the original line voltage will reduce its overload capacity, and in a motor will cause the motor to operate on overvoltage, the effects of which will be more fully explained later in this article. In general, the effect of dropping one slot will be less in a machine with a large number of slots and a small number of poles. In any machine if the effect is not greater than 7 per cent no harm will result from reducing the pitch, except in cases where the machine is already being pushed to or beyond its rated capacity. In this case any change that tends to reduce the capacity should be avoided.

Another case in which a better job resulted from decreasing the pitch came up recently. This was a stator in which the winding was

Table VI—All Practical Connections for 22- and 24-Pole, 3-Phase Windings

See heading of Table I for instructions on using these tables.

Twenty-two-Pole, Three-Phase

Original Connection	Series		2-Parallel		11-Parallel		22-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.091	.053	.045	.026
Series—Delta	1.73	1.00	.865	.50	.157	.091	.078	.045
2-Parallel—Star	2.00	1.16	1.00	.58	.182	.105	.091	.053
2-Parallel—Delta	3.46	2.00	1.73	1.00	.314	.182	.157	.091
11-Parallel—Star	11.00	6.38	5.50	3.19	1.00	.580	.50	.290
11-Parallel—Delta	19.03	11.00	9.52	5.50	1.73	1.00	.865	.50
22-Parallel—Star	22.00	12.76	11.00	6.38	2.00	1.16	1.00	.58
22-Parallel—Delta	38.06	22.00	19.03	11.00	3.46	2.00	1.73	1.00

Twenty-four-Pole, Three Phase

Original Connection	Series		2-Parallel		3-Parallel		4-Parallel		6-Parallel		8-Parallel		12-Parallel		24-Parallel	
	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta	Star	Delta
Series—Star	1.00	.58	.50	.29	.333	.193	.25	.145	.165	.097	.125	.073	.083	.048	.041	.024
Series-Delta	1.73	1.00	.865	.50	.577	.33	.432	.25	.29	.165	.216	.125	.145	.083	.073	.041
2-Parallel—Star	2.00	1.16	1.00	.58	.66	.386	.50	.29	.33	.193	.25	.145	.167	.096	.083	.048
2-Parallel—Delta	3.46	2.00	1.73	1.00	1.15	.66	.865	.50	.577	.33	.432	.25	.29	.167	.145	.083
3-Parallel—Star	3.00	1.74	1.50	.87	1.00	.58	.75	.435	.50	.29	.375	.217	.25	.144	.125	.073
3-Parallel—Delta	5.19	3.00	2.59	1.50	1.73	1.00	1.29	.75	.865	.50	.648	.375	.432	.25	.216	.125
4-Parallel—Star	4.00	2.32	2.00	1.16	1.33	.77	1.00	.58	.66	.385	.50	.29	.33	.193	.165	.097
4-Parallel—Delta	6.92	4.00	3.46	2.00	2.30	1.33	1.73	1.00	1.15	.66	.865	.50	.577	.33	.29	.165
6-Parallel—Star	6.00	3.48	3.00	1.74	2.00	1.16	1.50	.87	1.00	.58	.75	.435	.50	.288	.25	.145
6-Parallel—Delta	10.38	6.00	5.19	3.00	3.46	2.00	2.59	1.50	1.73	1.00	1.29	.75	.865	.50	.432	.25
8-Parallel—Star	8.00	4.64	4.00	2.32	2.66	1.54	2.00	1.16	1.33	.77	1.00	.58	.66	.386	.33	.193
8-Parallel—Delta	13.84	8.00	6.92	4.00	4.60	2.66	3.46	2.00	2.30	1.33	1.73	1.00	1.16	.66	.585	.33
12-Parallel—Star	12.00	6.96	6.00	3.48	4.00	2.32	3.00	1.74	2.00	1.16	1.50	.87	1.00	.58	.50	.29
12-Parallel—Delta	20.76	12.00	10.38	6.00	6.92	4.00	5.19	3.00	3.46	2.00	2.59	1.50	1.73	1.00	.865	.50
24-Parallel—Star	24.00	13.92	12.00	6.96	8.00	4.64	6.00	3.48	4.00	2.32	3.00	1.74	2.00	1.16	1.00	.58
24-Parallel—Delta	41.52	24.00	20.76	12.00	13.84	8.00	10.38	6.00	6.92	4.00	5.19	3.00	3.46	2.00	1.73	1.00

Table VII—Possible Number of Connections for 2-to 24-Pole Windings

No. of Poss. Conn.	No. of Poles	Series	2-Par.	3-Par.	4-Par.	5-Par.	6-Par.	7-Par.	8-Par.	9-Par.	10-Par.	11-Par.	12-Par.	13-Par.	14-Par.	16-Par.	18-Par.	20-Par.	22-Par.	24-Par.
2	2	X	X																	
3	4	X	X		X															
4	6	X	X	X			X													
4	8	X	X		X				X											
4	10	X	X			X					X									
6	12	X	X	X	X		X						X							
4	14	X	X					X							X					
5	16	X	X		X				X							X				
6	18	X	X	X			X			X							X			
6	20	X	X		X	X					X							X		
4	22	X	X									X							X	
8	24	X	X	X	X		X		X				X							X

tight. This was a 120-slot, eight-pole, 220-volt stator with a pitch of 1 and 13 or 80 per cent pitch. The winding had pulled and insulated diamond-shaped coils. Before pulling the new set of coils it was decided to try the 1 and 12 pitch which would increase the winding angle and make a better job. The 1 and 13 chord factor is $[12 \div (120 \div 8)] \times 90 = 12/15 \times 90$ or 72 degrees. The sin of 72 deg. = 0.951. The chord factor of the 1-and-12 pitch is sin $[11 \div (120/8)] \times 90 = 11/15 \times 90 = 65.97$ or sin 66 degrees, which is 0.913. Then by using the 1-and-12 pitch the voltage would be reduced to $220 \times (0.913 \div 0.951) = 220 \div .96 = 211.2$ volts. This is a reduction of $220 - 211.2 = 8.8$ volts. In percentage this is $(8.8 \div 220) \times 100$ or 4 per cent and the motor will operate satisfactorily with this reduction, as a 7 per cent change is allowable. Now if this stator had 180 slots and was a six-pole machine with 80 per cent pitch, which equals 24 slots or 1 and 25, and the pitch was dropped to 1 and 24, the reduction in voltage would be less. From Table V the chord factor for the 80 per cent pitch is 0.951. The 1 and 24 chord factor (76.7 per cent pitch) is 0.93. The new line voltage is $220 \times (.934 \div .951)$ equals 216 volts. This is $(220\text{-}216) \div 220 \times 100$ equals 1.8 per cent reduction. Comparing this with the reduction of 4 per cent in the previous case proves the statement that the greater the number of slots and the less the number of poles, the smaller will be the effect of one slot dropped.

Another case in which time was saved by eliminating a cross-over coil occurred on a recent rush and overtime rewinding job. The motor had a 120-slot stator, rated 20 hp., 440 volts, three-phase, 60 cycles, ten-pole, 675 r.p.m., connected series-delta, pitch 1 and 9, coils with ten turns of one No. 11 round d.c.c. wire wound 2×5 cross-over, diamond shape, and connected in a two-layer, threaded-in winding. To save time the winding was checked to see if the cross-over could be eliminated.

There were 120 coils or forty per phase and 40×10 equals 400 turns per phase. Then with a series-delta connection the volts per turn is $440 \div 400$ equals 1.1. Now using a five-turn coil of two No. 11 wires in parallel in a series-star connection the voltage would be $5 \times 1.1 \times 40 \times 1.73$ equals 380.6 which is 16 per cent under the required voltage. This, however, was raised by increasing the pitch and chord factor. The original pitch was 1 and 9 which gives a chord factor of 0.866. Full pitch would, of course, give 100 per cent chord factor. Then with the full pitch (1 and 13) five-turn coil and series-star connection the line voltage would be $380.6 \div .866 = 439.4$ volts, which is close enough. Checking the end room it was found sufficient to take the longer coil.

With over-voltage the magnetizing current will vary as the square of the voltage, if the iron is working below the saturation point. This current should be expressed as a percentage of the total current. The iron losses will be increased approximately 1.8 times the per cent voltage increase. This value holds only for increases of voltage of 10 or 15 per cent.

The copper losses will be lower, due to the fact that with a higher voltage a smaller current will be required for the same hp. rating.

The slip (or the difference, expressed as a percentage, between the no-load and full-load r.p.m.) will vary inversely as the square of the voltage or:

$S_1 \div S_2 = V_1^2 \div V_2^2$, wherein S_1 equals the per cent slip at rated voltage, V_1, and S_2 is the per cent slip at the higher or new voltage, V_2. The power factor will be slightly lower at the increased voltage. The maximum or pull-out and starting torques are increased in proportion to the square of the voltage. The decrease in copper losses more than offsets the increased iron losses.

For 10 to 15 per cent voltage difference from standard, the friction and windage can be assumed to be the same, as these two depend upon a variation in speed and the percent of change in speed is too small to affect these factors to any extent.

If the motor were not loaded to its maximum rating the effects of over-voltage would be more noticeable. The lighter the load the greater the iron loss will be in proportion to the copper losses. Also, the decrease in power factor at light loads is more evident as the magnetizing current is increased. With a 15 per cent voltage increase and one-half load, the motor is quite likely to run hot enough to burn out. But on the other hand if the motor were overloaded and the voltage increased, the motor would run cooler, as the torque increases as the square of the voltage and the speed remains the same. Hence with an increase in torque the hp. rating would be increased with a lower current consumption. *(Continued on page 158)*

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

DANIEL H. BRAYMER
Editorial Director

Assisted by

G. A. VAN BRUNT F. E GOODING A. J. WHITCOMB

Chicago, March, 1924

Penny Wise and Pound Foolish

INASMUCH as mechanical and electrical superintendents are held strictly responsible for production delays, they should have the same control of specifications and requisitioning of equipment and supplies as they do over the maintenance and inspection of equipment. The following incident shows what serious consequences may result when the plant maintenance organization does not specify the equipment and supplies that are to be used:

During a regular overhauling period the oil was drained from one of the motor bearings of a 3,000-hp. flywheel motor-generator set which supplied power to the main drive motor of a reversing blooming mill. The oil cellar was cleaned and refilled to the proper level with new oil. The next morning the motor-generator was started and the customary inspection was made to see that the oil rings were running freely and carrying up oil. A couple of hours later it was noticed that the bearing in which the oil had been changed, was heating. Preventive measures were taken but before they became effective, the babbitt melted and the shaft dropped. Fortunately, the motor was stopped before any damage was done to the rotor or stator windings.

After considerable trouble, the motor shaft was jacked up, the pedestal removed and the bearing taken out. Inspection disclosed no dirt or other foreign matter on the shaft or in the oil. Examination of the oil, however, revealed that it was of a somewhat lighter grade than was formerly used. A new bearing was put in the motor and the original grade and make of oil was again used. The bearing caused no further trouble.

From an investigation of the source of the oil it was found that a somewhat lower price was offered the purchasing department and that department substituted an oil made by another manufacturer, but claimed to be of the same grade as the original oil. The plant maintenance organization was not informed of this change and when a workman was sent to the storeroom after oil for this machine, the substituted oil was given him. The initial saving on the price of the oil was less than $4.00 a barrel. The direct loss caused by the substitution of the oil was a damaged bearing, the time and trouble of replacing it, and a half day's delay of the mill. The cost of a new bearing and of installing it was in the neighborhood of $100.00. The production delay was serious, as the blooming mill was the bottle neck of the plant. Furthermore, if the hot bearing had not been discovered in time, several thousand dollars' worth of damage might have been done to the motor winding.

The initial cost may be a little higher when the plant organization specifies material to be bought, but the operating expense per unit of finished product will be far lower in practically every case.

Where Some Profits Lie Hidden

EVERY business must show a profit or it cannot continue long to operate. When it ceases operating, all jobs and wages stop with it. Well-managed concerns expect to make a certain profit on each dollar's worth of business. Ordinarily this may be increased either by getting more business or by unanticipated economies. Those who ignore as of little consequence the miscellaneous savings in materials or methods which cannot be visualized in physical shapes, but take the form of a decrease in time out of productive machinery through better attention, inspection and maintenance, need only consider the relative return resulting from handling more business or from economies in handling its existing volume. To realize an economy of $1,000 a year, and many savings will total this much, would require an increase in business done of $20,000, assuming the profit to be 5 per cent on each dollar's worth of this business.

Men responsible for inspection and maintenance have a big opportunity to assist in making these miscellaneous economies, particularly in plants where suggestion boxes or other methods are used to get the ideas of the men on possible betterments of methods or equipment. The work of these men takes them over the plant where they learn first-hand of the troubles of the machine operators on the various jobs. Their training leads them to look for the source of the trouble, which is often some distance from the point where it shows up, and offer a solution or at least make a suggestion. Companies which have successful suggestion box methods have found the men in the maintenance department one of the best sources of worth-while ideas.

Men with ideas, particularly those which help make profit, are the ones who get ahead.

Don't Let Notions Take the Place of Facts

A POWER transmission engineer recently called our attention to an instance where he was asked to recommend a drive for a machine driven by a silent chain with which an unusual amount of trouble had been experienced. When he went to the plant to make an investigation the manager refused to let him see the machine in question, with the explanation that he could give the engineer all of the necessary information. When the latter refused to give his services under such conditions, permission was at last granted to make an inspection.

This engineer found that the chain drive in question was the most important drive in the plant and was rated at 350 hp., but pulling a load which he knew by previous experience amounted to nearly 500 hp. The manager absolutely refused to have a test made to determine the power demand on the drive. He "knew" it was not over 350 hp.—and that settled it. As the only way out of the situation the engineer sent in an order for a 350-hp. chain, and instructed the factory to ship a 500-hp. chain. That particular chain has now been in operation for some time and has given no trouble whatever.

Whether the engineer should have resorted to this trick need not be discussed here. There is no question, however, of the absurdity of the manager's attitude. His refusal to seek and use facts instead of beliefs cost his company many thousands of dollars and this loss would probably have continued if he had had his way.

Although this is an extreme example, it is typical of similar experiences which this engineer and probably many others have had with executives who clung very tenaciously to their hazy or erroneous notions of the size or type of equipment required for a particular service.

Pre-conceived notions may sometimes serve a useful purpose, but when they do not square up with the facts they should promptly be discarded. You can fool yourself as to the power requirements of a drive, but you can't fool the motor or other elements of the drive—and it does not pay to try it.

The Peg on Which Blame Is Hung

DURING the last hour of the turn when all hands are striving to get out the few extra tons of steel to make the day's quota, a vital machine, such as the shear approach table, stops. The electrical department is called immediately and all hands assume the attitude that someone there is the cause of the delay. Now why is the electrical department the peg on which the blame for such faults is hung?

The reasoning is usually something like this: The machine has stopped. The motor is intended to run it. Since the motor doesn't move, it must be an electrical trouble and, therefore, the chief electrician has to get busy. He will probably say that in the majority of his calls the trouble has not been with his end of the machine. However, he inspects his part of the equipment until he feels sure that it is all right. But he cannot prove his case until the wheels are turning again and he usually has to hunt until he locates the mechanical fault that caused the delay. He will tell you that in a great many cases he finds that the bearings of the drive have become so worn as to cause the gears to bind; or the oiler has not oiled the bearings at the regular time—hence the shafts are gripping; or some bolts holding the roller shaft bearings came loose, causing a misalignment which made the table bind; or any of the other mechanical faults that creep in.

Mechanical trouble is something that can be seen from its very inception. Careful and regular mechanical inspection while the machine is in operation will disclose a loose bearing, a misalignment of gears or shafts, hot bearings and the like, before the fault becomes dangerous. Steps for temporarily correcting it until it can be repaired can usually be taken so as to continue production. Electrical faults are more difficult to locate and do not always make themselves evident until the damage is done.

The chief electrician has a hard job at best—don't assume that he alone should have to locate mechanical troubles to clear his own skirts. The master mechanic and his millwright are also a part of the maintenance force and they too can and will help when their part in the work carries recognition as well as some blame for the things that happen.

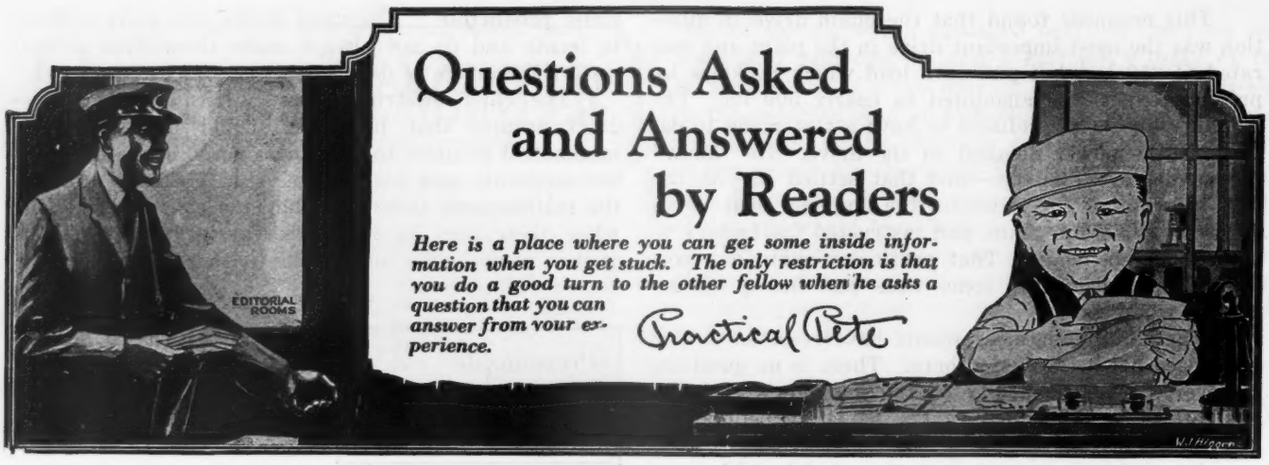
Preventable Losses from Break-Downs

IN A RECENT address before the Society of Industrial Engineers, Guy H. Rumpf, Works Manager of Joseph T. Ryerson & Sons, Inc., made a very practical analysis of the factors that control production in an industrial works. The four essentials of a production unit he set down as: (1) Plant, (2) Material, (3) Men and (4) Management. In regard to the plant he made the following comment:

> There are few ideal plants, due to the fact that these plants have grown, having been built up from time to time as the particular business increased. These additions were probably not made with ultimate planning in view and as a result, unless a growing business decided to rebuild their plant, the layouts are not always the best that could be desired. * * * It never pays to buy poor equipment and many times it can be proved that it will be cheaper to scrap certain equipment and buy new equipment. In order to prove this, however, it is necessary to determine the saving which can be made with new equipment, taking into consideration the interest on the investment and the depreciation of the particular machine that may be purchased.
>
> In this connection, all equipment needs to be taken care of and repaired. If it is not kept up, it will soon deteriorate and wear out long before it should. It is a good plan to inspect all equipment at regularly determined intervals and repair it in accordance with the needs indicated by such inspection, rather than allow equipment to run until it breaks down and then repair it out of necessity.
>
> In the first case, repairs do not cost as much and you can choose the time when you wish to make them. In the second, repairs will always cost more and the machine is sure to break down when you need it the most.

In most plants that have been operating for, say ten years, the greatest increase in profits at the end of any year will not come from the increase in work turned out but the attention paid to avoidable wastes in handling a normal volume of work with breakdowns reduced to a minimum, machines running at normal capacity continuously and little loss of time due to transporting materials to and from machines so that as the material flows through the plant the time it is worked on between raw state and finished form is the highest possible percentage of the total time each part is traveling through processes of production. Breakdowns and interruptions are one of the factors which make losses from non-productive time hard to estimate. Inspections and repairs must be considered as a regular routine on a day-to-day basis and an essential part of any production schedule.

The economy advocated by the Chinese doctor is possible here. He gets pay for his services while the patient is well, but he prevents the loss of earnings through inability to work. This Chinese doctor idea is overlooked in many plants and consequently they pay for the repairs and the loss of productive time as well, when the latter might be saved by a little regular prevention here and there.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Conventional Diagram of Four-Pole, Three-Phase Motor—Can some reader give me the conventional diagram, as in Dudley's book, together with the method of connection, of a four-pole, three-phase motor, wound on the 120-deg. principle, such as is found in certain Wagner motors?
Portland, Oregon. V. G. W.

* * * *

Installing Signal Lamp on Single-Phase Electric Furnace—Can any of our readers tell me how to install a signal lamp on a single-phase electric furnace?

There is a switch on the primary side of the transformer that furnishes current for the furnace, and I wish to find some way of installing a light between the top carbon electrode and the bottom contact, so that when the switch is released by a short circuit from a piece of metal falling against the carbon electrode, we can tell by this light whether the electrode has been raised high enough to break contact with the metal, before throwing in the switch.

The winding in the transformer forms a permanent circuit, so that we cannot apply any outside source of current to operate this light. It would save us considerable money if we were able to connect up a light of this kind, as the cost of carbon electrodes and contacts for the switch runs into considerable money. I shall appreciate very much any suggestions which you can give me.
Michigan City, Ind. P. V. H.

* * * *

Changing 25-Cycle Motor to Operate on 60 Cycles—I have a General Electric repulsion-induction, single-phase motor which has the following nameplate data: No. 3124538, type RI 546-2-1-1500, form C, 25 cycles, full load speed 1,495 r.p.m., volts 220, amp. 5, volts 110, amp. 10, 1 hp. continuously, 50 deg. C. Some of the part numbers are: pulley end bearing lining, cat. 329792; stator coil spec. 205425; rotor spec. 3005030.

The rotor dimensions are 5 in. (diam.) x 3⅛ in. It has twenty-three slots, 1⅛ in. deep, and sixty-nine bars. The stator has thirty-two slots. I thought this was a standard 2-hp., 60-cycle RI frame but find that this is not the case. I should like to know: (1) If the above motor is any standard 60-cycle RI frame. (2) Complete data for rewinding this motor for 110-220 volts, 60 cycles, 1,800 r.p.m., single phase. (3) What will be the rating of the motor after rewinding?
Portland, Ore. V. G. W.

* * * *

What Causes This Motor to Spark at the Brushes?—I have a 35-hp., four-pole, shunt-wound motor that drives a fan. The armature has seventy coils, lap-wound. Under load this machine draws 280 amp. at 115 volts and has always sparked viciously. The brushes are of the Bayliss type and I find the neutral point with a voltmeter as closely as one can. When I stone the commutator down the motor runs satisfactorily for a day or so and then sparking begins and the commutator develops low bars and seems to flatten or sink.

I am wondering if this armature was designed for a four-pole machine, as it has seventy bars and coils. This number is not divisible by four without a remainder and thus throws the neutral point in the center of a bar. I shall be very grateful if some reader can explain what causes the sparking and tell me how I can overcome it.
New York, N. Y. C. E. K.

* * * *

Winding Data for Rotor of Repulsion-Induction Motor—Can someone tell me the correct way to wind the rotor of a single-phase, repulsion-induction motor which has four poles and four brushes? The motor appears to be about 1 hp. The nameplate is missing, but the motor has thirty-four slots and seventy-six bars. The coils have four turns, wound two in hand, using No. 13 d.c.c. wire. The coil pitch is 1 and 9. Nine pairs of the bars were shorted, I believe in the order X, 7X, 6X, 7X, 6X, 7X, 6X, 7X, 6X, 6, the X representing a shorted pair of bars. I have tried six or seven common pitches without success, the motor locking at certain points in each case. Is it impossible to start up with this commutator?
Lewistown, Pa. G. R. F.

* * * *

Winding Data for Washing Machine Motor—Can some reader supply me with the winding data for a Westinghouse washing machine motor? According to the nameplate this is a 60-cycle, 1,700 r.p.m., motor, 220-110 volts, 2-4 amp. The laminations are 6¼ in. in diameter; the inside bore is 3½ in. and the axial length of the core is 2⅝ in. There are twenty-four slots, ¾ in. deep and ⅜ in. wide. The teeth are ⅛ in. wide at the top and ¼ in. wide at the base. This motor employes a starting winding. I shall appreciate any information which you can give me. S. McP.
Hercules, Calif.

* * * *

Rewinding Westinghouse Fan Motor—I wish to rewind a Westinghouse Whirlwind fan motor, style No. 280598, to operate on 110 volts, 60 cycles, alternating current. Can some of the readers of INDUSTRIAL ENGINEER tell me the proper size of wire to use and how many turns should be put in each coil. Apparently this motor had only two coils? Is this correct?
Marietta, Ohio. E. L.

* * * *

Winding Data for Type KT-4 General Electric Motor—Will some of the readers of INDUSTRIAL ENGINEER kindly tell me the proper winding for a type KT-4, form C, General Electric motor, No. 678120, 3 hp., 1,800 r.p.m., 220 volts, 60 cycles? What size wire should be used and how should the coils be connected? I wish to have this motor operate on 50 cycles. Should any change be made in the original winding?
Pasadena, Calif. H. B. S.

* * * *

Operating 60-Cycle Repulsion Motor on 25 Cycles—I have a ½-hp., 110-volt, 60-cycle, single-phase repulsion motor with a new winding in the rotor. The only current available here is 110 volts, 25 cycles. I wanted to test this motor out and when I connected it to the line it would start nicely, but as soon as the mechanical switch cut out the rotor would stop instantly, as nearly as I could see. Then just as soon as the brushes got back on the commutator the rotor would immediately start and then stop again, and so on.

The coil pitch and commutator connections are the same as in the old winding. I have checked up the winding for shorts and polarity and it appears to be all right. I should like to know, (1), if this motor will run satisfactorily on 60 cycles. (2) What makes the motor start and stop this way on 25 cycles? I shall appreciate any suggestions which readers of INDUSTRIAL ENGINEER can give me.
Massena, N. Y. F. A.

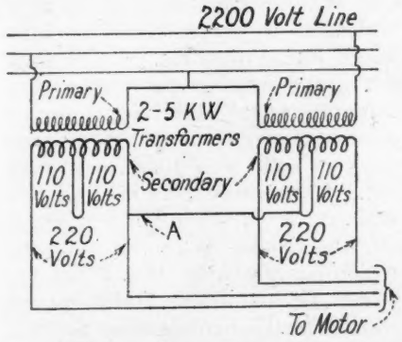
Answers Received To Questions Asked

Putting Tires on Wheels of Bandsaws— Will someone be kind enough to tell me what is the best method of putting tires on the wheels of bandsaws? I shall appreciate this information very much.
Chicago, Ill. J. W. C.

J. W. C. asked in the January issue for the best method of putting tires on wheels of bandsaws. I retired two machines recently and he may be interested in learning how I did it. First, I removed the old tires from the wheels and sandpapered the latter until all of the old rubber and cement was removed. Then I applied a liberal coat of cement made for this purpose and stretched the new tires on over the wheels. I allowed the cement to dry over night before using the bandsaw. If a special, prepared cement is not furnished with new tires, a coat of heavy varnish may be used instead of this, with very satisfactory results. E. L. WAY.
Marietta, Ohio.

* * * *

Trouble in Operating Two-phase Arc Welder Set on Three-phase Circuit— I had occasion recently to operate a two-phase, four-wire, 220-volt, 60-cycle, 1,800 r.p.m., 5-hp. Lincoln motor, which is direct connected to a Lincoln welding generator, on a three-phase, 2,200-volt, 60-cycle circuit. The transformer connection shown was tried. I found that the motor would start but in a short time would get very hot. The wire at *A* was cut and then the motor did not heat so much, so that by stopping the

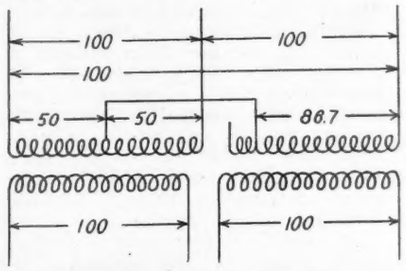


machine about every hour and letting it cool off I was able to do the welding, but too much time was lost. I wish some of the readers of INDUSTRIAL ENGINEER would tell me if this connection is correct and if so, what causes the motor to heat.
Tyrone, Pa. H. L. F.

In answer to the question asked by H. L. F. in the December issue, of INDUSTRIAL ENGINEER, I believe that his motor would have operated more satisfactorily if he had left out the line marked *A*. As a solution of his problem I would suggest that he use the General Electric Co.'s type MTQ transformer or employ the T connection with two single-phase transformers. EARLE N. DILLARD.
Chief Electrician,
Booth-Kelley Co.,
Springfield, Ore.

* * * *

In reply to the question by H. L. F. in the December issue, I would say that it would be impossible to obtain two-phase current with the connection which he used. The motor was being supplied with two phases having a phase angle of 120 deg. instead of 90 deg. as required. This condition would greatly reduce the torque for a given current and cause the motor to over-heat at its rated output. I do not believe that the wire *A* in his diagram would have any effect on the heating of a four-wire, two-phase motor.



Scott connection of transformers for changing three-phase to two-phase, or the reverse.

The correct connection for obtaining two-phase current from a three-phase circuit is shown in the diagram. As will be seen, the Scott connection is used on the three-phase side. Transformers for this purpose are on the market.
LYLE HENDRICKS.
District Electrician,
Pickands Mather Company,
Hibbing, Minn.

* * * *

In reply to the question asked by H. L. F. in the December issue, beyond any doubt the trouble is in the transformer connections employed in changing from three-phase to two-phase. The scheme of connections shown would result in a severe unbalancing of the two phases. H. L. F. should use what is known as the Scott connection. For this purpose one transformer should have a 50 per cent tap on the primary and the other transformer should be tapped at a point 86.6 per cent from one end. In actual practice, a 10 per cent tap would be enough, unless the transformers are to be paralleled with another bank using different connections.
PHILIP N. EMIGH.
Chief Engineer,
Mountain Water Supply Co.,
Indian Creek, Pa.

In answer to the question by H.L.F. in the December issue, from the diagram of transformer connections shown it is evident that an unbalanced voltage condition causes the motor on the welder to heat. If the ratio of one of the transformers is changed from 10 to 1 to 8.6 or 9 to 1, better results will be obtained. The standard method of three-phase to two-phase transformation is by means of the Scott connection, which can be found in all handbooks. The diagram shown by H.L.F. shows the unbalanced T connection.
General Electric Co., L. B. MORRILL.
Boston, Mass.

* * * *

Trouble with Portable Electric Drill— I have been having trouble with a Westinghouse, ⅜-in., portable drill. This drill operated satisfactorily for two years and then began running at only half speed. Occasionally it would start off on normal speed, but soon drop back to half speed. I rewound the stator and when this did not clear the trouble I rewound the armature, with no better results. Instead of winding the armature on a form I wound it by hand. So far, I have not been able to get it to run at normal speed.

Another portable drill, a Van Dorn, came in recently with the armature roasted. I wound this armature by hand and it, too, ran at half speed. I rewound the armature again, this time on a form but so far have not been able to get it up to full speed although the field coils have been tested out and seem to be all right. The armature core number of the Westinghouse drill is 12-A-876; the Van Dorn armature coil number is Code 8406. Both drills are designed to operate on 110-volt alternating current. I shall appreciate it very much if some reader can tell me what is the matter with these drills.
Philadelphia, Pa. R. I. G.

With reference to the question asked by R. I. G. in the December issue of INDUSTRIAL ENGINEER, we do not make any drills, but in checking up the stock order, 12-A-876 which R. I. G. states was stamped on the armature, we find that this order number covers a 110-volt motor which we supplied to the U. S. Electrical Tool Co. of Cincinnati, Ohio, for their type CU ⅜-in. drill. For this application we supplied our type AD universal motor, which has the compensating type of field winding. It is our supposition that when R. I. G. rewound the stator he became confused and wound both fields the same; that is, he connected the main and compensating windings in such a manner that he made a four-pole motor instead of a two-pole motor. This would account for the motor operating between half speed and full-load speed, although it

would not run at exactly half speed with the two brush outfit.

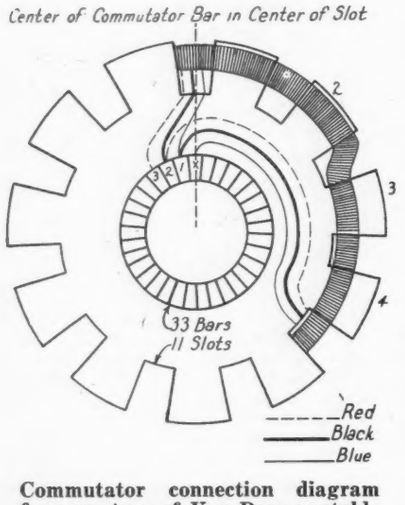
It is also possible that the armature is short circuited, which would also help to slow down the speed. I would suggest that the motor be sent to our nearest service station, in this case Philadelphia, to be rewound. A. M. STAEHLE.

Westinghouse Elec. & Mfg. Co.,
East Pittsburgh, Pa.

* * * *

Answering R. I. G., whose question appeared in the December issue, my experience would seem to indicate that the portable drills mentioned have one or more short circuits in the armature. The usual tests for these should be made.

The Van Dorn 110-volt armature, code 8406, is wound with No. 26 d. s. c. wire. Since there are three times as many commutator segments as armature slots it should be wound with three wires in hand. Each coil



Commutator connection diagram for armature of Van Dorn portable electric drill.

consists of fifteen turns around four teeth. The commutator should be assembled with the center line of the segments opposite the center line of the slots. The diagram shows how the commutator should be connected.

Electrical Engineer, E. L. CONNELL.
The Van Dorn Electric Tool Co.,

* * * *

Method of Soldering Leads to Commutator Bars—Can any of the readers of INDUSTRIAL ENGINEER give me the following information: (1) The design of a transformer for soldering the leads to the commutator risers with the aid of carbon electrodes. (2) I have done armature winding on large machines, but would like to know the best way of soldering leads to commutators of fractional-horsepower motors, such as fans. I should like to know the type of soldering iron to use, and other information that will help me to save time.
San Francisco, Calif. S. H. S.

In the December issue S. H. S. asked for information on the best methods of soldering commutator leads. On small armatures we use a medium-size iron and apply it to the brush surface of the commutator, instead of the necks. By using an iron of the proper size, the whole commutator is heated and with plenty of solder and flux you can make a quick and thorough soldering job. The commutator is covered with solder—in fact it looks like a lead commutator, but this is all taken off when the commutator is turned. No extra cut or time is required, as the commutator always has to be turned after a rewinding job. A. C. ROE.

Detroit, Michigan.

* * * *

What Causes this Magnet Switch to Stick?—We have on a crane hoist a 440-volt a.c. magnetic limit switch which fails to open about one-half of the time when the current is taken off the magnet coil. Although the core is laminated, there is apparently enough magnetism left to hold the switch in. All of the working parts are clean and free. Will someone kindly suggest a remedy for this trouble?
Selby, Calif. J. T. C.

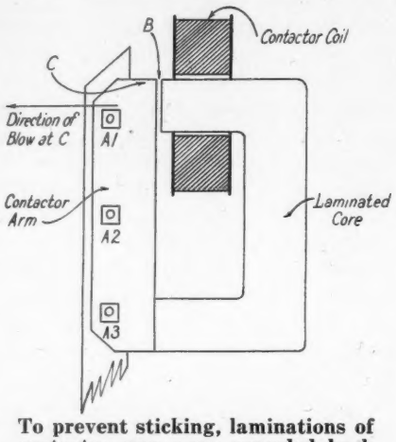
In answer to the question by J.T.C. in the December issue of INDUSTRIAL ENGINEER, without knowing the exact type of magnetic switch in question it is impossible to determine the trouble definitely but generally when a switch fails to drop when the current is taken off the holding coil, it is due to improper adjustment at the solenoid. Of course, when there is no current in the coil the solenoid should drop by gravity as the permanent magnet is not strong enough to hold the armature up. There is generally an adjusting screw and locknut to adjust the space between the core and armature. If not, a weight may be hung on the armature which will be heavy enough to make it drop and yet not too heavy to allow the armature to pull in when the coil is energized.

Of course, there is always a possibility of a short in the control connections which will allow at least part of the current to pass through the coil when it is apparently dead.

General Electric Co., L. B. MORRILL.
Boston, Mass.

* * * *

Referring to J. T. C's question in the December issue of INDUSTRIAL ENGINEER, I had about the same experience on the control of a large hoist. After carefully examining the switch I found the laminated core was so battered that instead of an air space at *B*, as shown in the illustration, the contactor arm hit flush with both ends of the core. By loosening nuts A_1, A_2 and A_3 and pounding the laminations of the arm at point *C*, I was able to move the laminations enough to allow a small air space between the contactor arm and the laminated core. After tightening the nuts the switch was put



To prevent sticking, laminations of contactor arm were pounded back to allow small air space, *B*, between arm and laminated core.

back in service and worked satisfactorily until new parts were received.

I hope this information will be of some assistance to J. T. C.

Goldfield, Nev. PHIL D. COMER.

* * * *

Replying to the question by J. T. C. in the December issue, the core and armature of an a.c. magnet are laminated not so much to prevent sticking from the residual magnetism as to prevent eddy currents which would overheat an a. c. magnet of any size. In addition, an a. c. magnet would take considerably more exciting current if it were made of solid iron, like a d. c. magnet. If magnetism is holding your magnet closed while the current is off, the trouble is in the air gap which has probably been reduced or eliminated by wear. If the magnet works freely when operated by hand, it should also work freely when operated electrically, provided that it has an air gap of 0.005 in. or over in the magnetic circuit. This air gap is always found on the leg nearest the hinge of the magnet and if this gap is less than 0.005 in., or the thickness of two or three sheets of writing paper when the magnet is closed and excited it should be increased by filing that leg or the part of the armature with which it lines up. The hinge should, of course, be examined first and the

wear taken up, if wear is the cause of the trouble. The further or outer leg of the magnet must not be filed as a carefully ground or scraped fit is very important, as well as a proper shading ring or coil if quiet operation is to be expected.

PHILIP G. BERNHOLZ.

East Orange, N. J.

* * * *

Operating Two-Phase Induction Motor on Three-Phase Circuit—I should like to know if a two-phase induction type or squirrel-cage motor can be run on a three-phase circuit, keeping the same speed and pulling the same load. I should like very much to have someone give me a diagram of such a hook-up and state if the two finishing ends of both phases or the start of one phase and the finish of another are hooked together. On what principles will the motor operate?

Chicago, Ill. J. H. B.

In the October issue J. H. B. does not give sufficient information concerning the present winding of his two-phase motor. When changing a motor from one phase to another, it is essential to have complete information concerning the original winding, on which to base calculations.

I have used the accompanying diagram to convert a two-phase, six-pole, two-circuit motor into a three-phase, six-pole, two-circuit motor. This will not give a three-phase motor of the same characteristics as the two-phase connection but will approximate it very closely. The correct three-phase voltage for this connection will be approximately 5½ per cent higher than the rated two-phase voltage. The three-phase power rating will be about 80 per cent of the two-phase power rating on the same temperature basis. If the old motor is a 40-deg. motor with a two-hour overload capacity it will carry approximately 96 per cent of the two-phase power rating on a 50-deg. continuous rating.

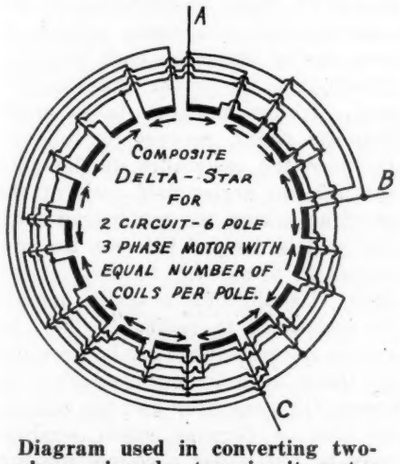


Diagram used in converting two-phase, six-pole, two-circuit motor into a three-phase, six-pole, two-circuit motor.

For a four-pole motor the correct three-phase voltage will be approximately 97 per cent of the two-phase voltage and the power rating the same as above.

The above explanation is based on a winding that will have an equal number of coils per pole in each phase in both two- and three-phase connections. For motors having an unequal number of coils per pole there will be a slight correction.

CHARLES R. SUGG.

Electrical Engineer,
Atlantic Coast Line Railroad Company,
Wilmington, N. C.

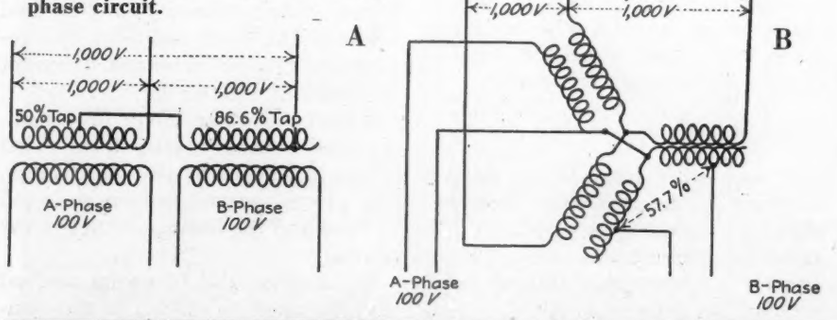
* * * *

In answer to the question by J. H. B. in a recent issue, in order to operate two-phase motors on a three-phase system, use two transformers, one as a main transformer with a 50 per cent tap on the primary winding and the other as a teaser with an 86.6 per cent tap on the primary. With this arrangement it is sometimes possible to use a teaser transformer with a different ratio from that of the main transformer. For instance, if the ratio of the main transformer is 10:1 as shown at *A* in the diagram, a 9:1 ratio transformer may be used for the teaser. Then the tap on the teaser transformer will be 96.2 per cent of the total primary winding or, 86.6 per cent divided by 0.9. Then if the Scott connection is used, the three-phase primary at, say 1,000 volts, will give a secondary at 100 volts, two-phase, as shown.

Or three transformers connected in star, assuming 1,000 volts primary to 100 volts secondary, may be used by joining two secondary windings in series and bringing out leads at two points at 57.7 per cent of the windings for the *B* phase, with the other secondary winding brought out at full voltage for its phase, as shown at *B* in the diagram.

New Britain, Conn. H. S. RICH,

Transformer connections for operating two-phase motors on three-phase circuit.



Trouble with Commutator Grinding Machine—I recently ground a commutator on a 150-kw. generator with one of the finest tools made, manufactured by the Jordan Commutator Grinding Company, but I did not have much success owing to the rapid wear of the corundum wheel.

When I set the wheel against the commutator it cut a groove, due to the rapid wear of the wheel. Before I could move it an inch along the face with the lead screw the wheel was worn so badly that it would barely touch the commutator. I tried setting it up for very light cuts and turning the lead screw rapidly but that did not help any and it is not a first-class job. The commutator is 14 in., in diameter, 12 in. long and turns at 1,200 r.p.m. The corundum wheel turns at 2,880 r.p.m., cutting against the direction of rotation of the commutator, is ½ in. thick and was 8 in., in diameter at first but when the job was finished it was only 5 in., in diameter.

I should like to know if this trouble is commonly experienced.

New Orleans, La. P. B. A.

In reply to P. B. A's question in the December issue of INDUSTRIAL ENGINEER, at one time I experienced similar trouble and found that it was caused by too high commutator speed and vibration of the grinder holder.

I got excellent results by setting the grinding machine so that it was rigid, using turn-buckles and pipe to support it. The ¼-hp. motor was placed on a small track on a heavy packing box so that it could be moved along with the feed screw. If the motor is set stationary the belt tightens when the grinder is feeding across the commutator, unless a long belt can be used to connect the motor and grinder.

I found that the best results were obtained by revolving the armature or rotor about 75 r.p.m. in the same direction of rotation as the grinding wheel. I used a Jordan 7-in. x ½-in. coarse wheel turning at 2,500 r.p.m. for cutting and a fine-grain wheel for finishing at the same speed. To compensate for wear of wheel the feed shaft was set 1/16 in. closer to the rear of the commutator, using a three-step, V-shaped cone pulley on

the motor to increase the speed for worn wheels.

WILLIAM J. MILDON.
Electrical Engineer,
Madeira-Hill Coal Mining Co.,
Philipsburg, Pa.

* * * *

With regard to P. B. A.'s question in the December issue, the trouble which he has experienced with his commutator grinding machine is, I believe, due to the fact that the commutator is rotating entirely too fast. I gather that it was rotating at about 1,200 r.p.m. and at this speed it would wear and cut down the corundum wheel exactly as a disc of soft iron will, if rotated fast enough, cut through a steel rail or girder.

If he can slow down the generator to say 50 or 75 r.p.m., I think his trouble will cease. Of course, there is a possible chance that the wrong grade of wheel was used.

If the prime mover of the generator is an engine it will be a simple matter to slow it down. If it is a motor-generator set, then a water rheostat may be necessary using the generator as a motor and applying full voltage to the shunt field and cutting the resistance in series with the armature. This arrangement will give a strong steady pull and there will be no tendency to race.

Chief Engineer, PHILIP M. EMIGH.
Mountain Water Supply Co.,
Indian Creek, Pa.

* * * *

With reference to the question asked by P. B. A. in the December issue of INDUSTRIAL ENGINEER, it is very probable that the selection of the cutting wheel for the Jordan commutator grinder is the reason for a poor job. Emery wheels are rated in two different ways: first, as to grain or coarseness, and second, as to grade of hardness. Inasmuch as the job was rough and unfinished, it is evident that the wheel was too coarse and as the wheel wore down quickly it was probably too soft. A wheel ¾ in. or 1 in. wide would be preferable for a commutator of the size mentioned. When grinding a commutator it is better to use a coarse wheel to start with and later finish with a finer wheel for the sake of smoothness and appearance.

General Electric Co., L. B. MORRILL.
Boston, Mass.

* * * *

I read with interest P. B. A's question in the December issue regarding trouble encountered in grinding commutators with a Jordan grinder. I have used this make of grinder on quite a number of machines, but on most occasions have experienced the same trouble that he did. If the commutator is long the wheel will chatter and wear down before a cut across is made.

On one occasion I had to grind a 200-kw., 80-r.p.m. generator which had a commutator 14 in. long and 35 in. in diameter. When I tried to grind it I found out that the wheel wore too fast to make a straight cut across. After deliberating for a while I hunted around until I found a compound steady rest from an old lathe. I put this lathe rest, or carriage as some call it, on a 10-in. x 8-in. timber placed across and bolted to the bedplate. Then I mounted the grinder in the tool post of the rest and operated it as a lathe tool. After that I had no more trouble with the grinder and made a nice, even job of grinding the commutator. I hope this account of how I overcame the trouble will be of some help to P. B. A.

NICHOLAS J. WEISS.
West New York, N. J.

* * * *

Equalizing Large Generators—I should like to have some reader of INDUSTRIAL ENGINEER tell me how to go about equalizing two 112-kw., 250-volt d. c. engine-driven generators and two rotary converters which furnish power at the same voltage. One of the converters is rated at 150 kw. and the other at 300 kw. They are supplied with alternating current from a public utility company and are modern units of up-to-date design. The engine-driven units are old-type, four-pole machines. I should like to equalize these units by means of resistance shunted across the series field. What losses would be incurred by this method of operation? How should the proper value of the resistance be determined?
Cincinnati, Ohio. R. G. P.

Answering the question asked by R. G. P. in the December issue, I would say that equalizing large generators should present no unusual difficulty when using the series field shunt he mentioned.

There may be some cross current at times due to the fact that the neutral point on the engine-driven generator shifts with the load and remains practically constant on the rotaries. I do not know of any method whereby the exact value of the resistance can be determined except by "cutting and trying."

Usually, German silver or a similar alloy is used in strip form. This comes in lengths of 100 ft. or more. The proper amount to use is found by trial and the balance returned for credit.

In practice, the following method may be used to obtain a flat-compounded generator: Connect one end of the strip to one end of the series field, making a permanent connection. Unroll, but do not cut off, 6 or 8 ft. of the resistance and *clamp* it to the other end of the series field coil. Next start up the generator and measure the exact voltage at no-load, and at ¼-, ½-, ¾- and full-load. If the voltage at full load is higher than the voltage at no-load, shorten the series shunt and try again until the voltage remains constant. Next, cut off the remainder of the roll of resistance leaving about 12 in. projecting beyond the temporary clamp. Follow the same method with the second rotary or generator. When this is done, test them for correct polarity using two lamps or a volt-meter of twice the voltage rating of the busbars.

If the voltage and polarity are correct, close the equalizer switches first, the series coil switches (positive) next and the negative switch last. The circuit breaker should be placed in the negative lead.

Now try the machines again at no-load, and at ¼-, ½-, ¾- and full-load. If their characteristics are approximately the same, which is very rarely the case, each machine should take its proper share of the load. If one machine takes more than its share, proceed as follows: Increase the resistance of the path through the series field coils of the machine taking too much load until the load is divided between the machines in proportion to their capacities. Usually only a small increase in resistance is needed. The increase in resistance may be provided by inserting a longer conductor between the generator and the busbar, or iron or German silver washers may be put under a connection lug.

If the generators have different compounding ratios it may be necessary to readjust the series field shunts to obtain uniform conditions. This explains why an extra foot was left on the series field shunt resistance.

The resistance strip used should be heavy enough to carry a large portion of the total load of the machine, although it may never be called upon to do so. Inasmuch as this method of equalizing is in every-day use, I do not believe that there is much loss in connection with its use. PHILIP S. EMIGH.

Chief Engineer,
Mountain Water Supply Co.,
Indian Creek, Pa.

Building Maintenance and Plant Safety

The object of this department is to give details of building maintenance procedure and best practice in safety work. Articles on ways of handling natural wear and tear or other depreciation, repair methods, rebuilding, extensions, cleaning and painting operations will always be welcome.

Helps in Erecting Radiators, Lineshafts or Motors on Ceilings

ERECTING or dismantling ceiling radiators, heavy pipelines, lineshafts, pulleys, or other similar equipment and placing or removing overhead motors—and almost every shop has considerable new work and alterations of this kind—is a task because of the difficulty in lifting the heavy pieces to the ceiling. Ordinarily, a chain hoist, even if it is possible to attach it to the ceiling, will lift these objects only part of the way. The plan used in some new construction work, as shown by the accompanying illustrations, enabled a smaller gang to do more than double what had been considered possible under former methods of construction. This same plan could be used for dismantling also.

In this case, hand-operated tiering machines (Economy Engineering Company, Chicago, Ill.) with an inverted platform were used so as to support the work close to the ceiling until it could be fastened. The first step is to build a long cradle of about 4-in. by 6-in. timbers. This is balanced on, and bolted to, the tiering machine platform. During the assembling of the radiator, say, the ends of the cradle are supported on horses which hold the platform at a convenient height for working. These horses, if of the right height, may be used by the men to stand on later, while fastening the radiator to the ceiling. It is best to elevate slowly at first and test to see if the load is in balance and will not tip.

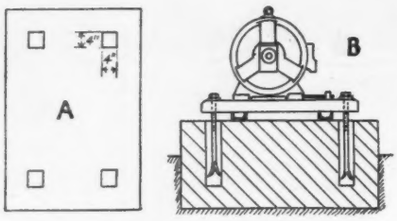
Overhead work may be speeded up by using a tiering machine to raise and hold the work at ceiling.

Lengths of lineshafting may be erected or dismantled in the same way. If solid pulleys are attached to the shaft before it is erected it will be necessary to block the shaft up on the wooden cradle so that it will be at least approximately level. Another time and labor-saving application is to use the machine to place or remove overhead motors.

Tiering machines with inverted platforms, such as this, are special and not ordinarily used for piling or tiering material in industrial plants because the platform does not go low enough. The standard type of platform which lowers almost to the floor may be used by building a special box-like extension to it so that the top of the box, when it is at its elevated position, will reach near enough to the ceiling.

Providing Means for Making Foundation Anchor Bolts Adjustable

IN THE September issue of INDUSTRIAL ENGINEER, Frank Harazim described on page 458 a simple method of making anchor bolts adjustable. A method which we have adopted and found very convenient for accomplishing this purpose when making motor installations may be of interest.



When the foundation is laid four square holes are made in it by the use of wooden mandrels. The motor with the anchor bolts is then put into position, resting on channel irons, and the holes filled with concrete.

When the foundation is laid it is provided with four square holes, as shown in *A* of the illustration. These holes are, of course, located to conform to the motor anchor bolts. For making these square holes we use a set of four wooden mandrels approximately 4 in. square, which will serve in almost every case.

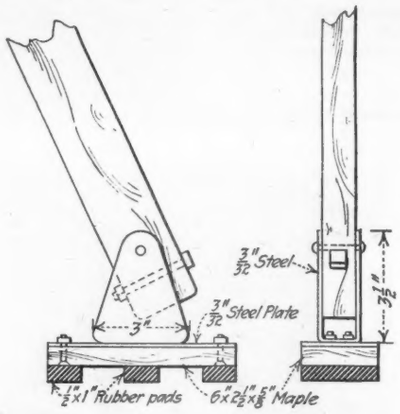
The motor, with the anchor bolts, is placed in its final position on two small channel irons laid across the foundation, as shown in *B*. Then the holes are filled with concrete.

When the concrete has set the channels are removed and the motor is let down. If the motor does not set level very thin iron plates may be used to raise the low end. The foundation is then finished all over with cement. We have used this method with satisfactory results in installing motors up to 200 hp. in size.

P. VAN HERK.
Bressany, Belgium.

Rubber Pads on Easily Constructed Safety Shoe for Shop Ladders

SLIPPING LADDERS are often the cause of a serious accident. To prevent this, one company uses shoes on all shop ladders, as shown in the accompanying sketch. These shoes are made from two pieces of 3/32-in. steel, a block of hardwood ⅝ in. thick, preferably maple, and



One of the advantages of this shoe is the light weight and the fact that it can be used on almost any type of flooring. Another advantage is that the ladder can be swung in either direction.

3½-in. by 1-in. rubber pads, 2½ in. long. The U-clamp is bolted to the flat steel plate, which prevents the maple block from splitting. The rubber pads should be glued on to the maple block, as well, or fastened by tacks or screws to prevent them from loosening.

Treating Concrete to Make Floor Surfaces Withstand Excessive Wear

IN MANY plants the concrete floors dust and wear away quite rapidly where they are subjected to heavy trucking. In the Brooklyn, N. Y. plant of the Englander Spring Bed Company, shown in the accompanying illustration, this problem has been solved. In this plant 200-000 sq. ft. of treated floor has been in use over a period of four years and has carried over 1,000,000 tons of traffic without showing signs of excessive wear.

These floors have been prepared by a special "Master Mix" treatment (The Master Builders Company, Cleveland, Ohio) which, it is claimed, not only makes them dustless but more resisting to wear. Here the treatment is applied in the topping layer. In treating these floors a 1-in. treated topping is recommended. This is made in the proportion of two parts of clean fairly coarse sharp sand to one part Portland cement and mixed thoroughly dry.

Next "Master Mix" is added to the gaging water gradually in the proportion of one gallon for every barrel of cement used. The cement is poured, floated and troweled in the usual manner. A second coating when the surface is sufficiently set will produce a hard smooth finish. The next step is to protect the surface of the cement from injury and keep it wet until the surface is hard. A layer of soft-wood sawdust, properly wet down, serves admirably for this purpose. This may require several wettings during this process, depending upon the atmosphere and the circulation of air, if the floor is in an enclosed area.

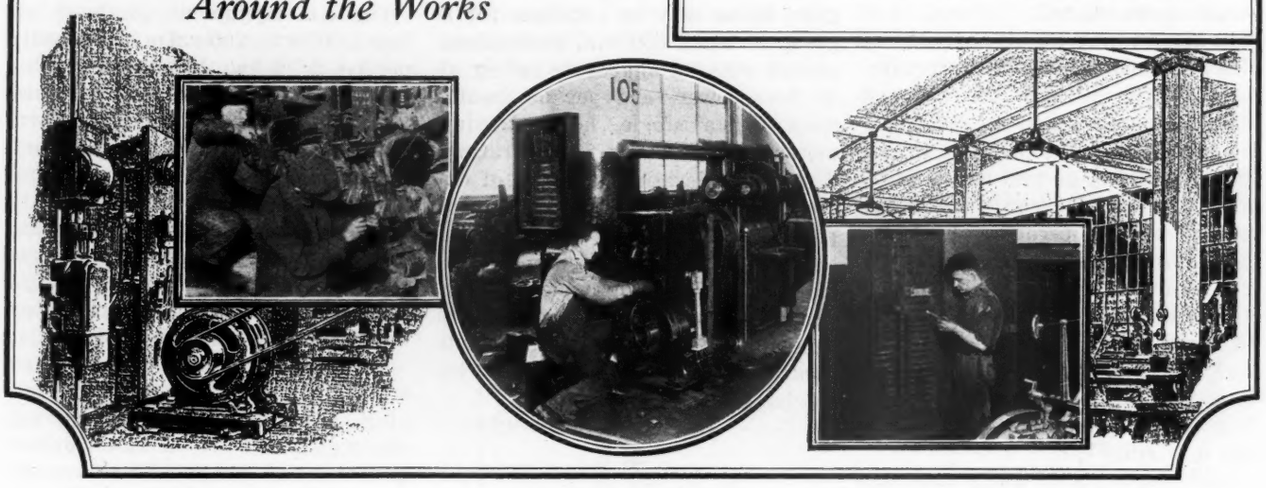
This concrete floor was specially treated to resist wear.

At the Brookyn plant of the Englander Spring Bed Company 200,000 sq. ft. of specially treated floor surface has handled over a million tons in four years.

Electrical Service

Around the Works

For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.

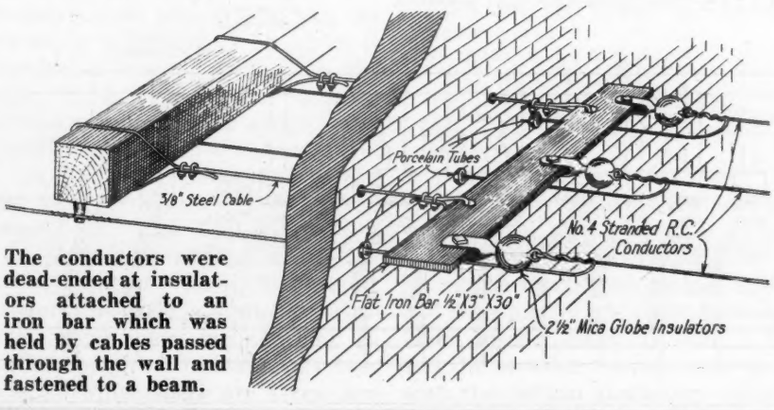


Easy Way of Dead-Ending Heavy Conductors at Old Wall

IN RUNNING a No. 4 line to supply a three-phase motor operating a sand cutter in a foundry it was considered advisable to avoid putting any strain on the outside wall of the building; this wall was only 12 in. thick and not very solid. Inasmuch as the line was quite long and rather tight, it was decided to anchor it to the first cross-beam just beyond the wall. This was done by dead-ending the three wires at globe insulators fastened to an iron bar 30 in. long, 3 in. wide and ½ in. thick, which was held just outside the wall by two steel cables ½ in. in diameter, which were passed through the wall and clamped around the nearest heavy cross-beam. Mica globe insulators with a clevis on one side and a ¼-in. eye on the other were used. The clevis was fastened to the flat iron bar by a ½-in. bolt. The steel cables were drawn through holes in the bar, which were well beveled to avoid cutting the strands, and double clamped.

The conductors were then carried through the wall in porcelain tubes and to the desired location, cleated to beams. By this scheme it was possible to keep the line tight without putting any strain on the wall.

New Britain, Conn. H. S. RICH.



The conductors were dead-ended at insulators attached to an iron bar which was held by cables passed through the wall and fastened to a beam.

Points to Be Watched When Wiring for Motors in the Industrial Plant

MOTOR wiring problems in the industrial plant should be considered from the standpoint of safety, reliability, flexibility, and efficiency. Refinements in construction due to the consideration of safety features are receiving much more attention at present than in the past, and their value is self-evident. The comparative importance of the item of reliability, which deserves more attention than it receives, depends upon a number of factors but particularly upon the quantity of production interrupted or the loss to the manufacturer when the machinery stops.

As an example, in one plant in which power for twenty operators is furnished by one motor, $130 per motor covers the entire cost of the equipment installed, including motor, belt, control and wiring. With an allowance of 25 per cent as the total annual charge-off for depreciation and obsolescence, the equipment charge per year is $32.50 or about ten cents a day for a single motor and its auxiliary fixtures. In contrast to this, the wages of the twenty operators dependent upon this single motor amount to $10 per hour. Thus a refinement in construction that will prevent three 20-minute shut-downs per year at a labor cost of $10 would warrant an increase in the initial cost amounting to about 30 per cent of the total; in other words, an additional initial expenditure of $40 charged off over four years or at the rate of $10 per year would be justified if it saved only one hour of time per year lost through shut-downs. Inasmuch as the wiring and installation cost amounted to approximately 40 per cent of the total cost of the motor equipment, 30 per cent of the total cost would be approximately 75 per cent of the wiring and installation cost. Thus it pays to get reliable equipment and material and by installing it properly decrease the

likelihood of failure. In a plant in which the cost per motor per operator is greater or less, a proportionate increase or decrease in expenditure for preventing interruptions would be warranted.

In determining the economical size of wire, above the minimum requirement as determined by the Code and other regulations and the permissible voltage loss, the probable life of the installation, as well as the number of hours per year the "energy saving" will be operative, should receive very careful consideration. The load factor is another important item and should be given due weight. In some plants the load factor is such that wiring mains large enough to handle the peak load are larger than the economical size for the average maximum load.

The possibility of costly interruptions of production as the result of the improper failure of a fuse or the opening of a circuit breaker renders advisable, in so far as practicable, the elimination of this equipment. One method of accomplishing this is by so designing the mains as to eliminate cutouts intermediate between the main switchboard and the motor. Further, such fuses, circuit breakers and control devices as are necessary should be placed where they will be readily accessible at all times. Also, from the standpoint of reliability an automatic circuit breaker, or a combination of an automatic circuit breaker and fuses frequently gives better service than fuses alone. In this construction the fuses are of such size as to blow only in the event of the failure of the automatic overload device. Automatic overload and no-voltage protective devices, especially for alternating-current motors, in convenient, enclosed form are available at a cost not exceeding and often less than that of fuses, when the saving resulting from the use of the circuit breakers is taken into consideration.

In determining the minimum permissible size of the main, allow ample provision for the maximum possible load. With a group of motors in which the control is such that only one motor can be started at one time, the maximum load is usually at the time of starting the motor with the heaviest starting current when all other motors of the group are running under full load. In general the wiring mains should be of sufficient capacity to provide for the simultaneous starting of as many motors as can be started together even though all other motors of the group are running under full load. Thus a line of No. 6 B. & S. gage mains may be sufficient for a group of small 550-volt, three-phase motors with an aggregate rating of 40 horsepower, and yet be insufficient for a single, heavy-starting motor not exceeding 20 hp. rating. These considerations are also of extreme importance from the standpoint of reliability.

Reliability and continuity of service require wiring of ample capacity, proper size of protective devices in accessible locations and adequate protection of these devices from mechanical injury.

Worcester, Mass. C. W. KINNEY.

Quick Method of Synchronizing Generators After Excitation Failure

SOME TIME ago I had an interesting experience in a hydroelectric power station where I was employed as an operator.

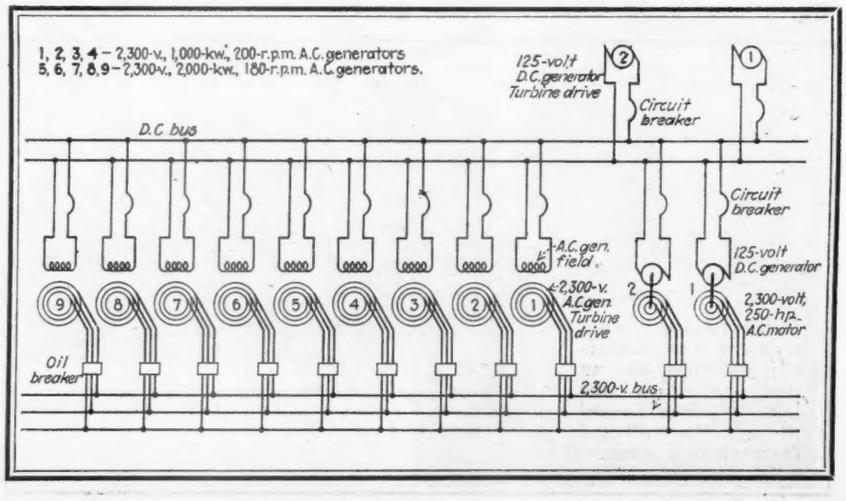
As can be seen from the illustration, the generating equipment consisted of two turbine-driven, and two motor-driven, direct-current exciters. The motors of the latter were fed directly from the 2,300-volt main bus. The four exciters could be operated in parallel with the d.c. bus which fed the a.c. generator fields. The turbine-driven exciters were used only for starting when the entire plant was down. There were knife switches and carbon circuit breakers in all the circuits leading to the d.c. bus, as well as in all a.c. generator field circuits leading from it.

The a.c. equipment consisted of four 1,000-kw., 200-r.p.m., 2,300-volt, and five 2,000-kw., 180-r.p.m., revolving-field a.c. generators, turbine-driven and controlled by Lombard governors. All of these generators fed into the one 2,300-volt bus through disconnects and oil circuit breakers. Under normal operation, the generator field current was supplied by the two motor-driven exciters. A Terrill voltage regulator was used to control the voltage.

On the occasion referred to, seven of the nine a.c. generators were running. The generator field current was supplied by No. 1 motor-driven exciter which had just about enough capacity to carry the load. Motor-generator No. 2 had been down for repairs. When starting it the floor man closed the compensator running switch before the starting switch was out. This, of course, short circuited the compensator, the short blowing off the cover. The running switch for No. 1 and the starting switch for No. 2 motor-driven exciter were located rather close together and when No. 2 shorted it not only went to ground but also shorted across the No. 1 running switch. The relay on No. 1 motor-generator immediately tripped the switch, leaving the seven a.c. generators running without fields and connected to the bus. The speeds of the generators, when running without fields, varied all the way from half-synchronous speed to about 65 per cent over synchronous speed.

To restore service in the shortest possible time the carbon circuit breaker on motor-driven exciter

When the motor-driven exciters were tripped off the line, service was restored by starting up one turbine-driven exciter under the load of the generator fields. As the exciter voltage built up, the generators pulled into step.


1, 2, 3, 4 – 2,300-v., 1,000-kw., 200-r.p.m. A.C. generators
5, 6, 7, 8, 9 – 2,300-v., 2,000-kw., 180-r.p.m. A.C. generators.
125-volt D.C. generator Turbine drive
Circuit breaker
D.C. bus
Circuit breaker
A.C. gen. field
125-volt D.C. generator
2,300-v. A.C. gen. Turbine drive
2,300-volt, 250-h.p., A.C. motor
Oil breaker
2,300-v. bus

No. 1 was opened, clearing it from the d.c. bus. The carbon circuit breaker on one of the turbine-driven exciters was closed. This exciter was then started with all the circuit breakers on the a.c. generator fields closed and the seven generators still running and connected to the a.c. bus. It took over 80 per cent gate opening on the exciter turbine for the d.c. voltage to build up, but as soon as it approached normal the a.c. generators pulled into step and did not have to be synchronized.

Service was thereby restored and the station was ready to carry full load in less than 2 min., while it would have taken at least 15 min. to synchronize all of the seven generators in the normal manner.

Possibly some other readers of INDUSTRIAL ENGINEER have had a similar experience. I would be interested in learning what they did in the emergency and whether they think my method would be likely to damage the equipment. Let us have a discussion of this through the pages of INDUSTRIAL ENGINEER.

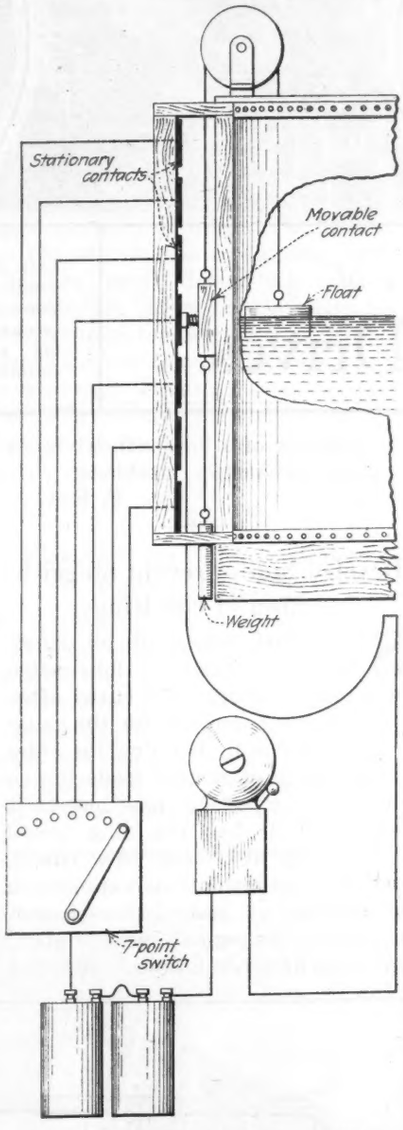
Belleville, Ont. J. H. GALLANT.

Float and Bell Device for Indicating Level of Water in Tank

A LARGE water tank located on the top floor of a factory building is supplied by two deep-well pumps located in the basement. Sometimes one pump is sufficient to keep the tank full of water; at other times both pumps are required. As a convenient means for keeping track of the varying water level in the tank, so that it may be known whether one or two pumps should run, the signaling system shown in the accompanying illustration was installed.

Instead of the usual indicator attached to the line connecting the customary float and weight, this device has a wooden block on which is mounted a moving contact in the shape of a copper stud passing through a spiral spring which bears against the collar on the contact end of the stud. The other end of the stud is inserted in a hole in the block.

As the water level changes, the moving contact closes the circuit through the various stationary contacts which are mounted on a wooden upright. The stationary contacts, of which there are seven, are made of copper strips ½ in. wide and 1/16 in. thick. A wire leads from each contact to a corresponding button on a 7-point switch mounted in the engine room. As shown, the arm of the 7-point switch is connected to the battery and bell; the other side of the bell is connected to the moving contact, which



A movable contact, whose position is controlled by a weight and float, closes the bell circuit at various water levels.

By shifting the arm on the 7-point switch the approximate water level may be determined, or by setting the arm at the point corresponding to any desired level the bell will be rung when the water has reached that level.

is actuated by means of the float and weight.

In operation the switch lever is set on the right-hand contact button and both pumps are started at maximum speed. When the tank is full and the movable contact is in touch with the bottom stationary contact, the bell rings. The switch lever is then shifted to the second contact from the right, one of the pumps is stopped and the speed of the other is checked somewhat. If the alarm is again sounded, the pump in service is speeded up, or the other one is started.

The engineers strive to keep the water in the tank at a level corresponding to a position between the two lower stationary contacts. If the water should drop below the level at which the bell circuit is closed through the second switch contact, the actual level can be found by shifting the switch lever to the left until the bell rings. A. J. DIXON.

St. Louis, Mo.

Two Methods Which Keep Tape on Conductors From Loosening

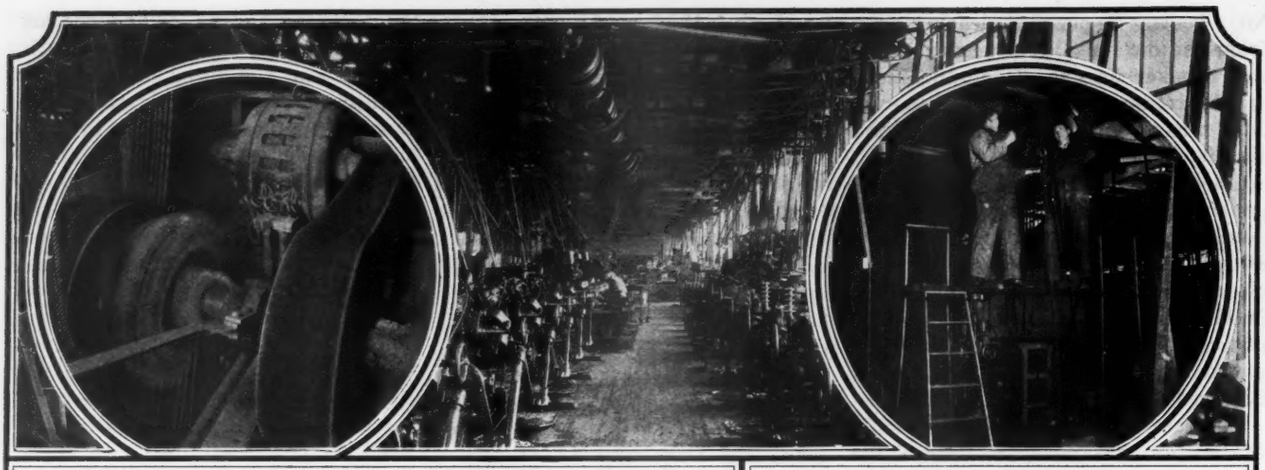
WHEN cables are brought up to the connection lugs at switchboards they are covered with friction tape. After being wrapped around the cables the tape is painted or varnished, both to give it a smooth surface to which dust and dirt will not adhere and to prevent it from absorbing moisture.

But in order to keep the tape clean it must be wiped down from time to time. Unless the tape wrapped on the cable is of unusually good quality, and the quality of the various makes of friction tape on the market varies more than does the quality of most electrical material, it will soon begin to dry out and lose much of its ability to stick to the cable or the other wrappings of tape.

Even good friction tape will become loose if it has been carelessly wound on. Also, the continual wiping down of the cables helps to loosen the wrappings, especially at the ends. This often results in an inch or two of the tape becoming loose at the end and hanging down. When conditions become too bad the loose end is cut off, but after a while more of the tape unwinds and has to be cut off. Eventually new tape may have to be applied.

There are two ways of preventing loosening. One way is to wrap the last turn loosely at first and pull the end of the tape down underneath it before giving it the final tension. The other way is to leave the end of the tape on the outside of the wrappings, but later tie it in place by binding around it several turns of strong, but soft and light, linen twine. G. H. MCKELWAY.

Westfield, N. J.



Mechanical Maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through transmitting equipment to all driven machines.

Emergency Method to Shorten Interruption of Service From Drive Failures

WHEN a motor driving a lineshaft in the plant of one Cincinnati machine tool manufacturer gives out for any reason, the interruption of service is only temporary. Extra motors with starting equipment are mounted on lift-truck platforms and can be taken to any lineshaft in a few minutes. An extra pulley is so placed on each lineshaft that the special motor on the platform may be deposited at the edge of an aisle at right angles to the shaft and the pulleys will be in line. Each motor has its own belt and as the lineshaft speeds are standardized, any motor will drive the shaft at the proper speed. Emergency leads are connected in and the group of machines can be going again in a few minutes.

The motor which gave out can then be inspected and removed if necessary. If it can be placed back in service shortly the extra motor is used until the repair is made; otherwise, either it or another motor is installed, on over-time if necessary, so that it does not interfere with the use of the production machines.

These extra motors and starting equipment are used, when not required for emergency service, to drive large machine tools when "working in" or fitting the bearings before sending out to the customer. In an emergency, one of these motors can be taken away from this work without anywhere near as large a loss as would be caused by the stopping of a lineshaft driving a group of production machines.

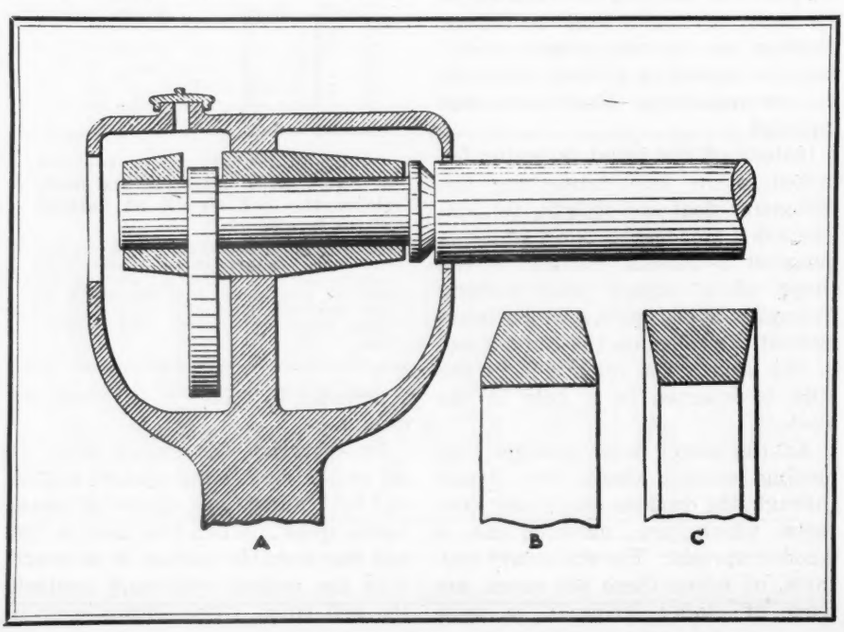
Chicago, Ill. F. E. G.

Beveled Sides Prevent Sluggish Action of Oil Rings

SLUGGISH action of oil rings, leading to improper lubrication of motor bearings, was cured after considerable searching for the cause of the trouble by beveling the sides of the rings of motors made in one factory. On testing these motors it was noticed that the ring would creep along at a very slow speed, two or three revolutions a minute on a machine of several horsepower, instead of the regular speed of about thirty to fifty revolutions. Although all journals and rings were made in large numbers and as nearly alike as possible, this trouble appeared on about one machine out of ten and disappeared nearly every time a new ring of the same size and shape was put in. Sometimes, of course, it was due to the ring rubbing against some projection on the casting, but more often no apparent cause was found by the assembling department.

At that time the oil rings were cut from a rather heavy brass tube with straight sides (see *A* in the illustration), making the cross-section rectangular in shape while the

The rings are beveled on either the inside or the outside to prevent them from sticking to side of oil ring slot.



journals had a straight slot 0.02-0.025 in. wider than the ring.

It was finally discovered that under certain conditions the ring would start with the machine and perhaps come up to normal speed but soon work itself toward one side of the slot and slow down, hugging closer and closer until there was only a very thin film of oil between the ring and the flat part of the journal.

Therefore, in an attempt to prevent sticking, three rings were removed and their sides were slightly beveled, as in *B* of the illustration. Then the trouble entirely disappeared. Since that time all oil rings are beveled either from the outside or from the inside, as at *C*, and there has been no sticking.

PHILIP G. BERNHOLZ.

East Orange, N. J.

Easy Way of Mounting Motor to Release Floor Space

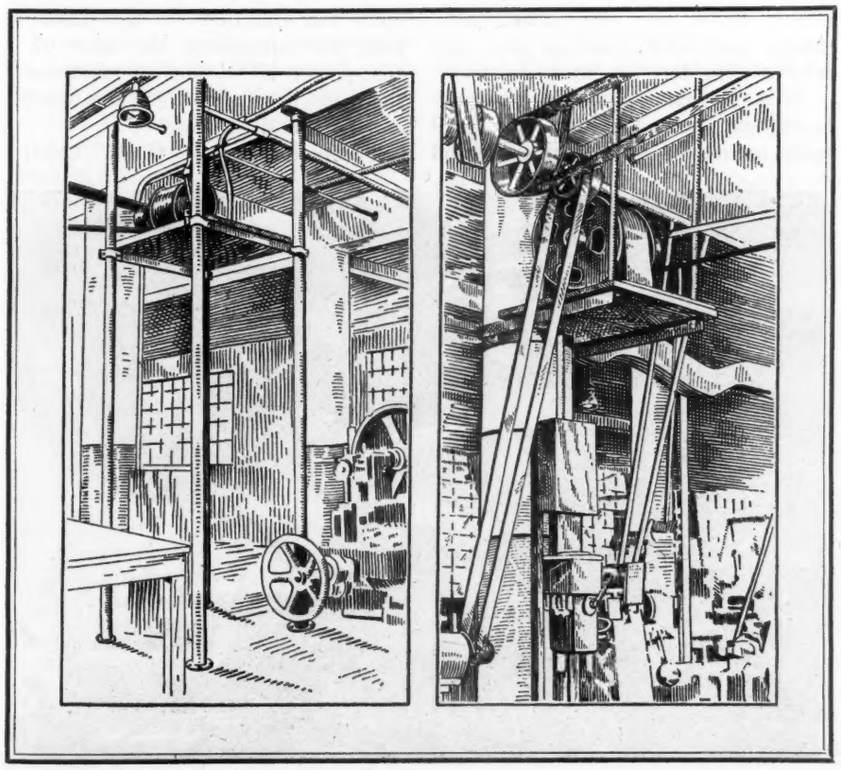
ECONOMY of floor space and convenience of control are now being obtained in one industrial plant by attaching the motor stand and control apparatus directly to the building columns, instead of mounting the motors on four iron pipes extending from the floor to the ceiling, as was formerly done. As the old supports were about 4 ft. apart, about 16 sq. ft. of factory floor space was wasted. In addition the supports usually interfered with the transportation of material.

The improved support is constructed by joining two half-circle iron bands around the column by means of bolts so that they cannot slip and attaching horizontal angle-iron pieces to the joints. The other ends of the angle-iron pieces are held in place by means of vertical ¾-in. rods attached to the ceiling. The motor is set on a wood platform built on the framework.

The switch box containing fuses and the motor starter can now be mounted on the column directly beneath the motor, so that considerable overhead conduit which was formerly used between the starter and motor is avoided. The motor can be easily cleaned and its location affords convenient inspection.

New York, N. Y. J. S. T.

The motor and control equipment are mounted on platforms which are supported by iron bands around the building columns and by rods from the ceiling.



Flat Spot on Driving Pulley Causes Trouble

SOME time ago we experienced a great deal of trouble with excessive sparking at the brushes of a generator. This case of trouble was so unusual that an account of what was done to prevent the sparking and how the real cause was finally discovered may be of interest to readers of INDUSTRIAL ENGINEER.

The generator was a 16-kw., 125-volt, 1,250-r.p.m., direct-current machine. When I found that I was not able to stop the sparking, I wrote to the editor of a well-known electrical magazine for suggestions. His reply stated that sparking might be due to one or more of the following causes: (1) Brushes not properly sanded; (2) brushes out of line; (3) too much vibration; (4) bearings worn so that armature is not centered between pole pieces; (5) high mica.

I checked up these points, but the sparking gradually became worse, and finally the generator had to be shut down because of excessive heating of the commutator. On my suggestion, an expert repair man was called in to test the generator for grounds and other defects. He said there was a ground in either the armature or commutator and, as there was no repair shop in town, the commutator was carefully removed and sent to a large shop in a nearby city. This shop reported that the commutator was in good condition and advised us to send them the complete machine for overhauling.

After going over the generator carefully, they were unable to find any defects and sent it back. But when it was placed in service again, the old trouble was just as bad as ever and the machine soon had to be shut down. At this time the generator was supported on wooden blocks which were bolted to the engine room floor. The floor had been blocked up underneath the generator and seemed to be very solid. The manager of the plant decided, however, to put the generator on a concrete foundation, as it was thought that vibration might be the cause of the trouble. But when it was placed on the new foundation, the generator behaved no better than it had before and had to be shut down again after running for only a short period.

An expert from another city was then called in and after a thorough inspection reported that there were no grounds present. He lined up and spaced the brushes and advised that the bearings be rebabbitted, the machine bolted down firmly, the commutator tightened up and turned down, and the belt straightened or replaced, as it was running somewhat out of line. All of this work was done, but when the generator was again put in service it ran very

little or no better than before. In addition, the brushes cut the commutator badly. As a possible remedy, we undercut the mica and installed a comb grounded to a water pipe for draining static electricity from the belt; all without results.

Soon the commutator had to be turned again, and this time the pulley was put in the lathe at the same time. We were using a paper pulley and found a small flat spot on it, so 3/32 in. was taken off.

After the commutator was turned down the generator was assembled and put in service, and we found to our surprise that all of the trouble had disappeared. The generator ran perfectly with no sparking or heating of the commutator. That was over two years ago and the machine is still running with no trouble whatever. We have often asked ourselves why we did not think about the pulley before. I do not know why we did not think of it as a possible source of trouble. This incident did, however, impress on all of us the fact that in practical engineering work the little things are sometimes the most important.

WALTER W. P. SINCLAIR.

Medicine Hat,
Alberta, Canada.

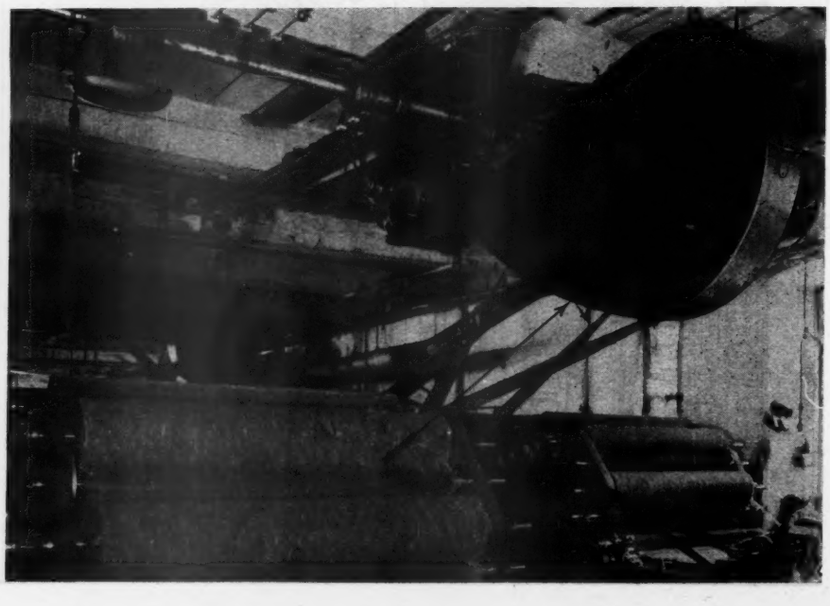
Savings Made With Silent Chains on Lineshaft Drives in a Textile Mill

FORMERLY eleven steam engines distributed about the Falls Schuylkill Mill drove lineshafts operating the various groups of textile machines. This system has been almost entirely replaced by smaller groups, each driven by a motor connected to its lineshaft through a silent chain. When this change was made the eleven engines and boiler rooms were replaced by one modern power plant with a consequent saving of the wages of six engineers and ten firemen. Also the single power plant gives better operating economies. In addition, much of the heavy friction load of the large lineshafting required for engine drive was eliminated by the subdivision into smaller groups.

On this installation motors operating at 1,700 r.p.m. drive the lineshafts at 105 r.p.m. This reduction is obtained through the sprockets and chain only and without any intermediate countershaft, as would be necessary with belt drive. If slow-speed motors had been used they would have increased the cost. Also the motors were placed close to the lineshaft; in one type of drive the distance between centers is only 3 ft. 6 in., while if a belt were used the distance would need to be about 8 ft. to 10 ft.

The silent chains (Link-Belt Co., Chicago, Ill.) require but little attention except for lubrication. They also run slack which lessens the friction on the bearings. Some of the chains have been in service about ten years at loads above their rating and are still in good condition.

ROBERT CALHOUN.
Chief Engineer,
John & James Dobson, Inc.,
Philadelphia, Pa.



One of the group drives of the Falls Schuylkill Mill.

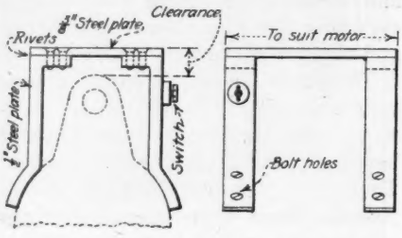
In this mill a large number of groups, each driven by an individual motor and Link-Belt silent chain, have supplanted eleven steam engines, each with its boiler room, driving large lineshafts. The large speed reduction—1,700 r.p.m. to 105 r.p.m.—is obtained directly without countershafting or other auxiliary reduction units.

Simple Method of Bracketing a Small Motor to a Bench Lathe

DIRECT motor drive for the bench or hand lathe is a worth-while convenience, particularly where considerable work is done and the operator depends on foot power to drive the lathe. In some small shops which actually have only occasional use for a power-driven bench lathe, a larger lathe than necessary is used because a power drive for the small lathe means installing shafting and pulleys at considerable expense.

It is possible, however, to apply individual motor drive to the small lathe by means of a simple method of bracketing, as shown in the accompanying illustration.

The bracket can be quickly and inexpensively made by bolting four steel-plate supports or legs to the headstock of the lathe. The plates should be about ½ in. thick and should be bent at the lower end to



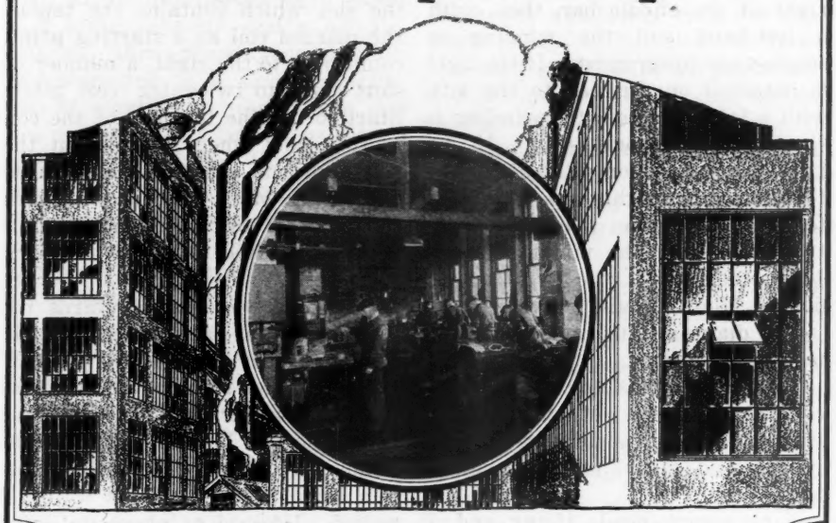
Four legs made of steel plate are bolted to the headstock of the lathe and support a platform which is large enough to receive the motor base.

conform to the shape of the headstock. These legs support a base plate of ⅜-in. steel which is fastened to the supports with machine screws. The motor, which will be about ¼ or ½ hp., should be bolted to the plate. A short belt drive is used and, if a step pulley is put on the motor shaft, speed changes can be made as usual by changing the position of the belt on the pulley.

A snap switch located on the motor bracket, or close to the lathe, and connected to the shop lighting system, will make it possible to operate the lathe independently of the other shop equipment. The convenience and simplicity of this installation will appeal to the user of a foot-power lathe, and in most cases the materials for making the bracket can be found in the shop.

Washington, D. C. G. A. LUERS.

In the Repair Shop



This section is devoted to repair work, large and small. Special attention is given to shop or bench tools and short cuts or improved methods. Contributions are always welcome.

Simple Indicator for Locating Repair Men in the Plant

WE HAVE found the device which is shown in the illustration so useful for locating electricians and other workmen that it may be of interest to the other readers of INDUSTRIAL ENGINEER.

As will be seen it consists simply of an arrow and a round metal disk or dial, which is divided into as many sections as there are departments in the factory. Both dial and arrow may be made of any suitable material, such as thin sheet iron, wood or fiber. A hole should be drilled through the center and the dial mounted, on a board or on the wall in any convenient location, by a screw so that it will turn freely. It is advisable to put a rubber washer back of the dial and one in front, before putting the screw in. The screw should then be tightened just enough to prevent the dial from being jarred out of position after it is once set.

The arrow, which carries the name of the workman, should also be drilled through the center and fastened in the same way as the dial, using rubber washers to keep it from turning too freely.

When in use the arrow should be set in the horizontal position and the dial turned around until the arrow points to the department where the electrician is working. When he comes back to the shop he sets the arrow in the vertical position; thus the shop foreman knows where he is.

Although the dial and arrow shown here are intended for use in the electrical department, they can, of course, be readily adapted for use in the millwright or other departments. ULYSSES F. COURTNEY.

Electrician,
Avery Company,
Peoria, Ill.

When the electrician goes out on a job he sets the arrow in the horizontal position and turns the dial until the arrow points to the department in which he can be found.

Motor-Driven File Lessens Work of Reaming Small Holes

AFTER reading G. A. Luers' article under the above heading, on page 607 of the December issue of INDUSTRIAL ENGINEER, in regard to using a motor-driven file to ream out small holes, I wish to point out one of the disadvantages in using the method he describes.

All of the round or "rat tail" files in my possession are cut with a right-hand screw pitch, and as an electric drill rotates in the same direction there is a tendency for the rapidly revolving file to be forced into the hole which is being reamed. If the hole is smaller than the largest part of the file disaster to the work, the file or the drill will follow immediately, unless the operator uses extreme care.

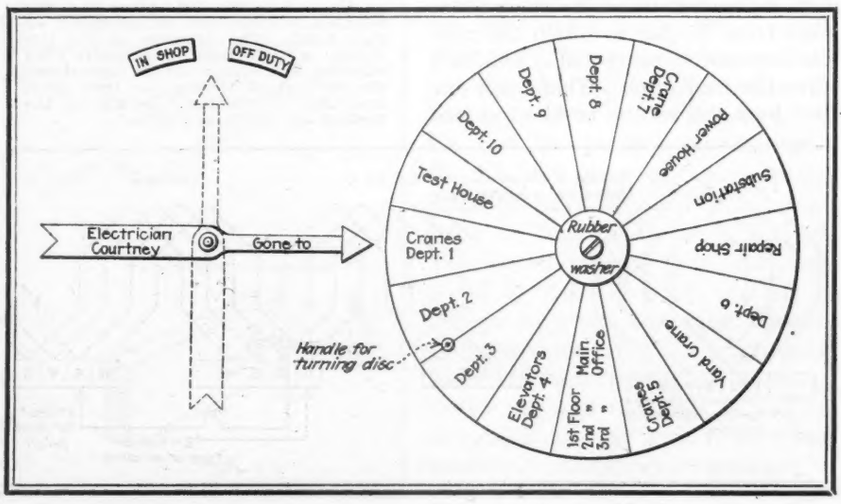
This statement is based on actual, and painful, experience.

Indian Creek, Pa. PHILIP N. EMIGH.

How to Find Commutator Pitch of Armature Coils with Test Lamp

IN A RECENT issue of INDUSTRIAL ENGINEER a reader asked for the best and quickest method of finding the commutator pitch of an armature coil with a test lamp. Perhaps a description of the method we use for this purpose may be of interest to other readers also.

On a lap-wound armature lift out of the commutator necks three adjacent top leads only; then apply one end of the test light to the middle top lead, making sure that the other two raised top leads do not touch it or the commutator. Then with the other test lead touch the bar on either side of the bar to which the middle top lead is connected. Only one bar will give a light providing, of course, that the winding is not completely burnt out and full of shorts. If a light is obtained when touching the bar to the right, the winding is single-lap progressive or left-hand; if the bar to the left lights out the winding is



single-lap retrogressive or right-hand.

If no light is obtained, however, on either side of the middle lead bar, this would mean a double-lap winding, right-hand or left-hand as above.

When checking the winding connection in this manner test between all raised leads and commutator bars to make sure that the section is free from shorts.

For a wave winding raise any three adjacent top leads as above and test for shorts; then with one test lead on the middle top lead, slide the other test lead around the commutator towards the bottom of the coil, or for a left-hand coil run the test lead in a clock-wise direction around the commutator and for a right-hand coil in a counter-clockwise direction.

One way a left-hand coil can be identified is as follows: Stand facing the armature at the commutator end; then if the top half of the armature coils are on your left the coils are left-hand, if on the right the coils are right hand. It is very important to get the direction of the test lead right on a four-pole motor as there are two lead pitches possible, that is, a long pitch and a short pitch, and by counting around one way one pitch would be had and then if a count is made in the opposite direction another pitch would result. The correct pitch is always found by moving the one test lead around the commutator towards the center of the coil to which the top lead is attached. Run the test lead around until a bar is reached that lights the test lamp; it should light on only one bar. This bar will be half-way around the commutator on a four-pole armature, one-third around on a six-pole, one quarter on an eight-pole, and so on. When this bar is located, mark it; then count over from the bar to which the middle top lead is connected. This will give the lead pitch. Then with one test lead still on the middle top lead try the other test lead on the bars on either side of the middle bar. If a light is obtained on the bar to the right of the middle bar, then, with a left-hand coil the winding is single-wave progressive. If the light is obtained on the bar to the left, with a left-hand coil, the winding is single-wave retrogressive. If no light is obtained on either bar, but the test lamp lights up when the test lead is put on a bar which is two over from the middle bar, or 1-3, either side, the winding is double (four circuit) wave.

The diagram illustrates the above method of testing.

When an armature is received completely burned out, that is, with turns and bars shorted, the following method of taking data can be used:

First remove hoods, if any, and all end- and core-bands and the core bands on the leads at the rear of the commutator. Then determine whether the coils in the winding are right-hand or left-hand. Select any one coil and mark it with white chalk, and also mark the commutator bar to which the top leads of this coil connect; then, if the winding is left-hand start to cut off the top leads only at the rear of the commutator, starting at the bar to the right of the bar to which the leads of the marked coil connect. Do not cut these leads. Remove all top leads three-quarters of the distance around the commutator. Next, estimate the coil pitch, which can be taken as the number of slots divided by the number of poles; use full-pitch figures. Then taking the slot which contains the top of the marked coil as a starting point, count over to the right, a number of slots equal to twice the coil pitch. Start to lift the top half of the coil in this slot; when possible cut the coil in two to enable it to be pulled out of the way. Proceed with each top half of coil, until enough tops have been lifted to enable the complete coils to be removed. When lifting coils work back towards the marked coil; as each top or complete coil is lifted or removed pull it around to the right on the commutator end as far as it will go, so as to expose the bottom leads. When removing complete coils cut the bottom leads of each coil as it is removed. Proceed as above until the marked coil is reached, which will then be completely exposed to view. It is then a simple matter to check the lead pitch and coil pitch.

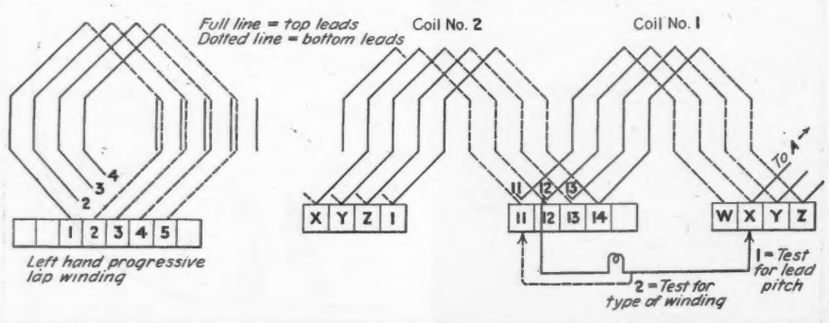
For a right-hand winding work to the left.

A. C. ROE.

Detroit, Mich.

Method of finding type of winding and commutator pitch of coils with test light.

On a lap-wound armature three adjacent top leads are lifted and one end of the test light is applied to the middle lead. The other end of the light is touched on the bars on each side of the bar to which the middle lead connects. If a light is obtained on the bar to the right the winding is single-lap progressive, or left-hand. A light on the bar to the left shows that the winding is single-lap retrogressive, or right-hand. The diagram at the left shows a left-hand progressive lap winding. The diagram at the right shows the method of testing for lead pitch and type of winding. Details of the method are given in the text.


Full line = top leads
Dotted line = bottom leads
Coil No. 2
Coil No. 1
1 2 3 4 5
Left hand progressive lap winding
X Y Z 1
11 12 13 14
W X Y Z
To A
1 = Test for lead pitch
2 = Test for type of winding

How One Shop Repaired a Broken Oil Stone With Shellac

A HARD oil stone, one of the favorites in a small repair shop, was repaired recently, after it had been dropped and broken through carelessness.

Inasmuch as the breaking of oil stones is a more or less frequent occurrence, the method of repair used in this instance may be of interest.

The stone was cleaned of oil by wiping the fracture and the adjacent surfaces with alcohol and placing the two pieces over the top of a small gas heater. After the stone was thoroughly heated, and the oil had been driven off, powdered shellac was sprinkled over both faces of the fracture, where it melted and flowed into the numerous crevices. While hot, the two sections were fitted together and clamped in an idle milling machine vise.

The shellac hardened as the stone became cool and the junction was not visible. Apparently this method of repair restored the stone almost to its original condition, as it has been constantly used since then and the line of fracture shows no evidence of separation. In fact, the user of the stone can hardly tell it had been repaired.

G. A. LUERS.

Washington, D. C.

Rewinding a Large Generator In Thirty-three Hours

A LARGE mill needed more generating capacity and a 500-kw. 220-volt, three-phase generator direct-connected to a Corliss engine, was at length purchased. The mill was operating on a two-phase system but we were assured that the new generator could be re-connected for two-phase and would operate satisfactorily, which it did up to about half load. Six months later the power demand increased and some trouble developed as the fields of the exciter and the generator heated to the danger point and we could not maintain the voltage at 180, much less at 230, its proper point.

Although some relief could have been obtained by improving the power factor it was decided to rewind the alternator with a two-phase winding. The large generator could not be idle for more than six days while it was being rewound. It was, therefore, necessary to plan the work so that the rewinding could be done with the least possible delay. The plant was idle on Sunday and so careful measurements were taken of the slots, wedges, and the existing winding. The machine was about 15 ft. in diameter and 3 ft. wide, with 360 open slots wound with diamond coils.

With this data, a new winding was designed having approximately 20 per cent more turns and by using flat wire instead of round it was found that the same cross-section of copper could be maintained. A wooden pattern was constructed representing twelve slots of the stator; then the coils were wound, dipped in insulating varnish, taped with oiled linen, sleeves put on the leads and the coils again taped with cotton tape and dipped. As the coils were finished they were placed on the wooden pattern and connected into groups of three, the number of coils per pole-phase-group. The slot insulation consisted of 0.015-in. fish-paper with a 0.030-in. strip in the bottom and between the coils. When the coils were finished all of the other material needed for the job was gotten together so that the work of rewinding could be started promptly on a Saturday noon.

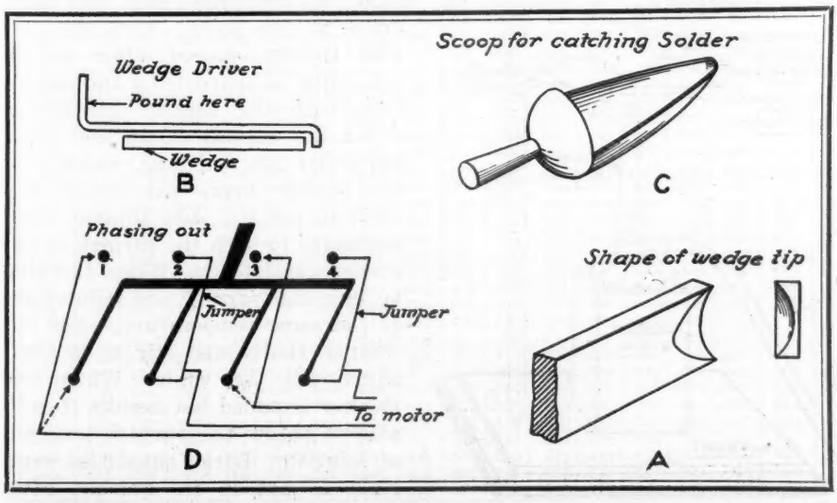
As soon as the machine was shut down the stator was slid shaftways on its supporting base. The maximum travel allowed only about 3 in. between the ends of the stator coils and the field coils. Stripping of the old winding started at once and as it was a thirty-parallel, two-phase connection, the end of each branch was carefully unsoldered from the connecting coil so that it could be used again on all four main leads to the switchboard. After driving the wedges out, the coils came out easily, as the insulation was old and brittle. The slots were then cleaned carefully and new insulation put in. Three men were employed in rewinding, with a helper to carry the material to them. One man put in the coils in groups of three; as was previously mentioned they were connected in groups at the shop in order to speed up the work. The other man cut the fishpaper cells flush with the top of the slots and drove the wedges in. The wedges were of maple and were made in two pieces to be driven from each end of the slot. The lower tip of the wedge was slightly concave, as shown at *A* in the illustration, so that it would fold the fish-paper over as it was driven in. The wedges were easy to drive in on one side but it was difficult to drive them in on the other side on account of the fields being in the way, and the tool shown at *B* was designed. This tool was easily made of ¼-in. by 1-in. iron and was very efficient. The coils were all in and wedged by 12:00 o'clock that night.

Next morning we started connecting up. As previously stated, the four main leads with their thirty connecting branches were carefully saved from the old winding and as the new winding was started in the same relation as the old, the leads fitted perfectly and the work was speeded up considerably. One repair man made the connections with copper clips and the other soldered them. The pouring method was used. A plumbers' pot was filled with solder and with a ladle and the scoop shown at *C* it was possible to solder in close quarters and still do fast work. The helper taped all the connections.

After everything was finished the machine was given a spray coat of an oil-proof, air-drying insulating varnish. Inasmuch as we had taken the precaution of starting the new winding in the same relation as the old one, phasing out was hardly necessary but for safety it was decided to check up on it. This was done, as shown at *D*, with the generator switch open. Wire jumpers were placed on contacts 2 and 4 and these two wires run to separate phases of a small two-phase motor. The other free wires were first placed on upper contacts 1 and 3 and when the motor started the direction of rotation was noted. Then the two leads from the small motor were placed on lower contacts 1 and 3 and, as was expected, the direction of rotation was the same as before. The repair crew went home at 5 o'clock Monday morning, after the generator had been given a short test run to see that it operated satisfactorily. By carefully planning the work and doing beforehand everything that could be done in the shop the job went along smoothly and was completed in about 33 hours instead of the six days that had been allowed. In recognition of their good work the repair men were given an extra week's pay and two days to rest up in—and I will say that it was well worth it.

ANTHONY J. MORRONI.
Denver, Colo.

Some devices used in rewinding large generator and method of phasing out.



Varnishes and Their Solvents

(Continued from page 126)

not have to be replaced by repeated thinning as often as is the case with the more volatile reducers.

Coal tar distillates such as F-160 are heavier than those derived from petroleum. They are more homogeneous and have a narrower cut. The solvent powers are the greatest of any of the materials described. They are not, as a rule, used alone but are mixed with petroleum distillates. By their use varnish bases that could not otherwise be used are put into solution. Only very small quantities, as a rule, need to be used. Varnishes containing them will be found to be extremely oilproof and extremely resistant to varnish solvents of all kinds. They should not, however, be used in the treatment of plain enameled wire coils, unless particular care is taken.

Turpentine is used to a very slight extent. Its solvent powers are great and hence the same objection to this product exists as is the case with the coal tar distillates.

Wood or denatured alcohol is used chiefly in shellac and quick drying finishing varnishes; that is, varnishes used over other coatings to give a glossy surface and, in some cases, for additional oilproofness. The big talking points for varnishes made with alcohol are the quickness with which they dry and the way in which they "set up" on the surface, and their appearance. They are not, however, insulators until thoroughly dry and they do not penetrate the interstices of the coils where insulation is most needed. They are brittle and have a tendency to crack, allowing moisture to enter the windings. They should only be used for outside protection of coils, for appearance and a hard surface.

Practical Points on Applying Varnish.—To insure uniformity of application you should assure yourself, first, that the varnish chosen is of uniform quality, and second, that the consistency at which you use it is always the same. The first should be guaranteed by your source of supply; the second must be regulated in your own shop. Furthermore, this consistency must be adjusted for the particular kind of work that is being performed. The varnish that is satisfactory for light coils is not at all adapted for heavy coils, nor for dipping armatures.

You should first thin the varnish to the point at which it works best on the particular kind of work at hand. Determine and record the specific gravity by means of a hydrometer, calibrated for liquids lighter than water, and thereafter see to it that the consistency does not vary. In other words, when the solvent evaporates, replace it. Remember, however, that the specific gravity is an indication of the consistency of a particular varnish only. It does not show a comparison between two different products. This is easy to understand because of the difference in gravity of the various types of solvents. Those already described range from 0.730 to over 0.800. Evidently the higher the gravity of the solvent the higher the gravity of the varnish, with like percentages of base.

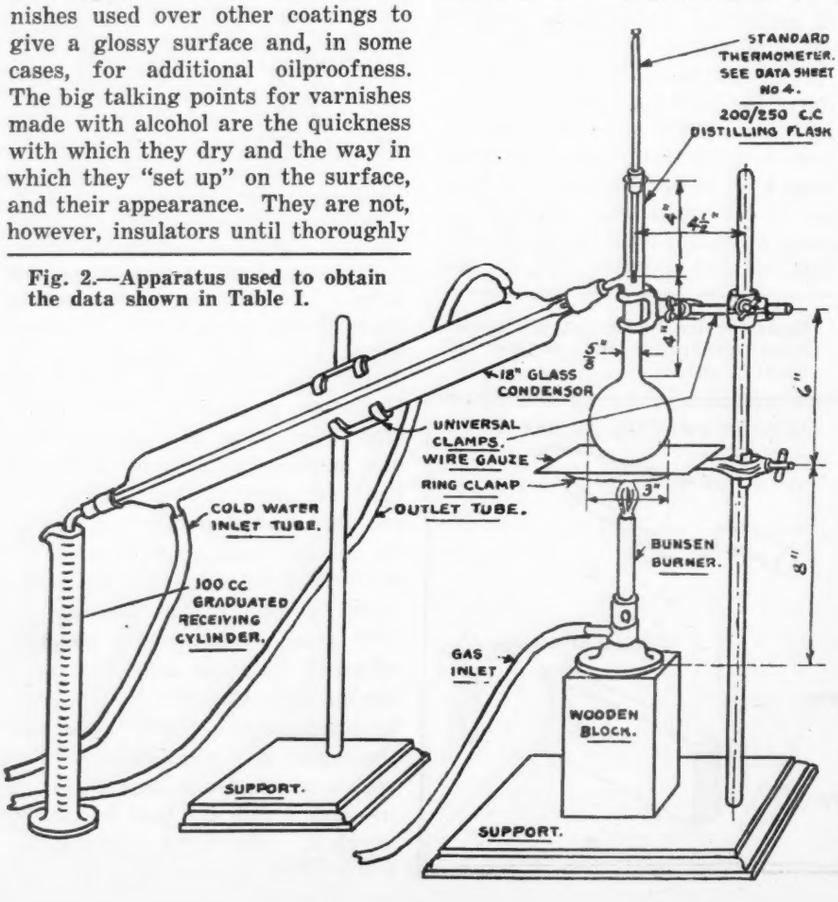


Fig. 2.—Apparatus used to obtain the data shown in Table I.

Varnishes expand with a rise in temperature and contract as it lowers, just as other liquids do. This of course varies the specific gravity It has been found that readings of the hydrometer vary 0.0007 for each degree variation in temperature on the Centigrade scale. Hence if the normal gravity of a varnish is 0.870 at 21 deg. C. the hydrometer readings when the varnish is at 26 deg. C. will be 0.870 minus 0.0035 or 0.8665. Although apparently thinner, the varnish will still be of normal consistency. Similarly, if the temperature were 16 deg. C. the normal consistency would be 0.870 plus 0.0035, or 0.8735, although it would appear to be somewhat thicker.

In practice there is generally so little difference in temperature when the gravity is taken before work is done that no account need be taken of this variation. It is of interest only so far as the changes in consistency between summer and winter temperatures are concerned. However, if the varnish is to be used at a higher or lower temperature for a considerable period, the proper consistency of the varnish should be determined for the work at that particular temperature and thereafter carefully maintained. The variations of the normal gravity with temperature changes are shown in Table II.

Directions for Care of Varnishes.—Perhaps a few directions for the care of varnishes will not come amiss at this point. Keep the varnish tightly covered when not in use. Buy a hydrometer and use it. Determine the specific gravity at which the varnish works best for a particular job and take readings of the gravity every day before you start to use it. Add thinner when necessary to keep the varnish at the proper consistency. When thinning be sure that varnish and reducer are at the same temperature. Add the thinner slowly and stir it in thoroughly all the while. When cold thinner is added too rapidly it is liable to throw the varnish base out of solution. Large quantities, especially if put in too quickly, often

cause a like result. Warmth aids the union; hence it is better to have varnish and reducer at a temperature of between 70 deg. F. and 90 deg. F. After the thinner has been added, continue to stir until you are sure that it has all been properly mixed. This can be determined by the "feel," that is the way it runs off the paddle and the absence of streaks on the surface of the varnish. If the varnish gradually seems to change with successive thinnings, although the thinner mixes thoroughly, there is probably something wrong with the reducer and you should consult the manufacturer.

If the thinner, in spite of the utmost care, seems to liver or precipitate the varnish base it is quite likely that it does not have the necessary solvent powers. The addition of a small amount of a more powerful solvent will often remedy this.

There seems to be an impression among many men that repeated thinning destroys the good qualities of the varnish. This is not true. Remember that it is the base of the varnish that gives you the insulation. The base does not evaporate. You are simply replacing, in the process of thinning, thinner which has disappeared. A very interesting test is what we term the "shop test." This is made by filling a container with a varnish of a known specific gravity. Leave the container open day and night and each morning take a reading of the gravity and replace the solvent which has evaporated. A good varnish will remain in solution for at least 30 days without livering or curdling.

In conclusion we would point out that in purchasing varnish you are really paying for the base or useful material. The solvent does not provide any insulation and hence you should see to it that you are obtaining a varnish having a maximum amount of base. This can be determined by means of the same apparatus shown for determining the distillation range of the solvents, but when made in this way the test is a very delicate one and very difficult for anyone to perform without considerable experience. Probably the better way for the ordinary shopman to determine this would be by the number of coils that could be treated with the varnish, making sure that when he is comparing it with another material that he is getting the same coating on the outside and the same degree of penetration on the inside. At best this test gives only rough results. However, the varnish manufacturer should be willing to tell you what percentage of base his varnish contains and to supply you with a certificate from an independent laboratory, provided your purchases warrant it.

In line with other commodities you get in insulating varnish just what you pay for. Be sure that the product you are using is the proper one for your purpose; then when troubles arise take your source of supply into your confidence.

Table II.—Variations from normal gravity of varnishes with changes in temperature.

When a varnish is to be used for a considerable period at a higher or lower temperature than normal, the proper consistency for the work should be determined at that particular temperature and thereafter carefully maintained.

DEGREES F.	SPECIFIC GRAVITIES.															DEGREES C.
32	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	.875	.880	.885	.890	0.0
34	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	.874	.879	.884	.889	1.1
36	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	.874	.879	.884	.889	2.2
38	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	.873	.878	.883	.888	3.3
40	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	.872	.877	.882	.887	4.4
42	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	.871	.876	.881	.886	5.5
44	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	.875	.880	.885	6.6
46	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	.875	.880	.885	7.7
48	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	.874	.879	.884	8.8
50	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	.873	.878	.883	10.0
52	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	.872	.877	.882	11.1
54	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	.871	.876	.881	12.2
56	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	.871	.876	.881	13.3
58	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	.875	.880	14.4
60	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	.874	.879	15.5
62	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	.873	.878	16.6
64	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	.872	.877	17.7
66	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	.872	.877	18.9
68	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	.871	.876	20.0
70	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	.875	21.1
72	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	.874	22.2
74	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	.873	23.3
76	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	.873	24.4
78	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	.872	25.5
80	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	.871	26.6
82	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	.870	27.7
84	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	28.8
86	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	.869	30.0
88	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	.868	31.1
90	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	.867	32.2
92	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	.866	33.3
94	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	34.4
96	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	.865	35.5
98	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	.864	36.6
100	.793	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	.863	37.7
102	.792	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	.862	38.8
104	.791	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	40.0
106	.791	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	.861	41.1
108	.790	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	.860	42.2
110	.789	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	.859	43.3
112	.788	.793	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	.858	44.4
114	.787	.792	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	45.5
116	.787	.792	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	.857	46.6
118	.786	.791	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	.856	47.7
120	.785	.790	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	.855	48.8
122	.784	.789	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	.854	50.0
124	.783	.788	.793	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	51.1
126	.783	.788	.793	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	.853	52.2
128	.782	.787	.792	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	.852	53.3
130	.781	.786	.791	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	.851	54.4
132	.780	.785	.790	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	.850	55.5
134	.779	.784	.789	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	56.6
136	.779	.784	.789	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	.849	57.7
138	.778	.783	.788	.793	.798	.803	.808	.813	.818	.823	.828	.833	.838	.843	.848	58.8
140	.777	.782	.787	.792	.797	.802	.807	.812	.817	.822	.827	.832	.837	.842	.847	60.0
142	.776	.781	.786	.791	.796	.801	.806	.811	.816	.821	.826	.831	.836	.841	.846	61.1
144	.775	.780	.785	.790	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	62.2
146	.775	.780	.785	.790	.795	.800	.805	.810	.815	.820	.825	.830	.835	.840	.845	63.3
148	.774	.779	.784	.789	.794	.799	.804	.809	.814	.819	.824	.829	.834	.839	.844	64.4

You Have a Part to Play in Safety Work

Here is a little jingle that carries a serious thought. It was written by G. H. McLaughlin, a crane man in Department 245 of Plant No. 1 of the Studebaker Corporation and appeared in that company's house organ, called "The Studebaker Co-operator."

A crane man's pathway is strewn with thorns,
With hardly a rose to relieve it;
Just to stand on the floor and look at him each morn
No person on earth would believe it.

He comes at your signal, glides along the steel path,
Though the consequence be what it may;
He takes up the slack and then hears the chain crack,
Slow music and flowers the next day.

Safety First signs are posted all over the shop,
And the men higher up really mean it.
But every darned bloke seems to think it a joke,
Or act like they never had seen it.

There may be other "rhyming bards" (unknown) among our readers. If so, we would like to hear from them now or any other time.

PRACTICAL PETE.

Voltage Changes on A. C. Motors

(Continued from page 137)

Or the number of turns per phase could be *decreased* in the desired percentage to get the effect of over-voltage. This can be carried up to the pull-out torque point of the motor, but for good results stop within 20 per cent of the pull-out torque.

The per cent change in these factors varies in different machines; hence we cannot say that a 10 per cent change in voltage of any machine will have a certain per cent change in each of the factors. It is obvious that the greater the per cent over-voltage impressed on the motor, the more the afore-mentioned factors will affect its operation.

With under-voltage the efficiency is lower, the iron losses are reduced, the secondary and primary copper losses are greater, and the power factor is slightly raised. With 10 per cent under-voltage the design of the motor would determine whether the full rated power could be delivered without overheating. With a 25 per cent reduction in voltage the horsepower rating would have to be reduced at least one-third.

The fact that the starting torque of an induction motor varies as the square of the applied line voltage makes it possible to determine the resulting starting torque at any voltage, or the required line voltage for a given starting torque. The following formulas can be used for setting auto-starters. Let: T equal torque at full line voltage; T_2 equal torque at reduced line voltage; V equal full line voltage; V_2 equal reduced line voltage.

Then, $T : V^2 = T_2 : V_2^2$ or $T_2 = TV_2^2 \div V^2$ and $V_2 = V\ [\sqrt{(T_2 \div T)}]$.

When the full-load torque of any motor is known, the voltage required for any lower torque value can be found. Assume a 220-volt motor which will start with 2.5 times full-load torque with full line voltage. For a certain drive only 75 per cent of full-load torque is needed at starting. What voltage is required?

Substituting in the above formula, $V_2 = 220\ [\sqrt{(.75 \div 2.5)}]$ equals 120.34 volts. This is 45.5 per cent of full voltage. Then if the lowest tap on the starter coil is 60 per cent the starting torque will be $T_2 = T\ (132^2 \div 220^2) = .90$ T, or 90 per cent of full-load torque.

If the full-load torque is known the torque at any voltage lower than the full-line voltage will be less according to approximately the square of the voltage, provided the change is not too great. For example, suppose the line voltage of a 440-volt motor dropped to 400 volts. The torque will be $400^2 \div 440^2$ equals 0.826, times the original torque. Or a reduction of 9.1 per cent in voltage resulted in 17 per cent less torque.

This is only approximately correct because the increased slip and other factors have not been taken into account. It is sufficiently accurate, however, for rough calculations where the voltage change is not too great. If the torque on the motor remains the same after this voltage drop, more current will be drawn from the line. This increased current might overheat the motor or, if the load were heavy enough, the motor would stop running.

When a motor is working on over-voltage and it is desired to keep the magnetic conditions, etc., the same, the turns per phase must be increased in the same percentage as the over-voltage. Likewise for under-voltage the turns per phase or coil must be decreased.

Table VIII—Sin Values for 45 to 90 Degrees for Use in Figuring Chord Factors

Deg.	°0.0	°0.1	°0.2	°0.3	°0.4	°0.5	°0.6	°0.7	°0.8	°0.9
45	0.7071	0.7083	0.7096	0.7108	0.7120	0.7133	0.7145	0.7157	0.7169	0.7181
46	0.7193	0.7206	0.7218	0.7230	0.7242	0.7254	0.7266	0.7278	0.7290	0.7302
47	0.7314	0.7325	0.7337	0.7349	0.7361	0.7373	0.7385	0.7396	0.7408	0.7420
48	0.7431	0.7443	0.7455	0.7466	0.7478	0.7490	0.7501	0.7513	0.7524	0.7536
49	0.7547	0.7559	0.7570	0.7581	0.7593	0.7604	0.7615	0.7627	0.7638	0.7649
50°	0.7660	0.7672	0.7683	0.7694	0.7705	0.7716	9.7727	0.7738	0.7749	0.7760
51	0.7771	0.7782	0.7793	0.7804	0.7815	0.7826	0.7837	0.7848	0.7859	0.7869
52	0.7880	0.7891	0.7902	0.7912	0.7923	0.7934	0.7944	0.7955	0.7965	0.7976
53	0.7986	0.7997	0.8007	0.8018	0.8028	0.8039	0.8049	0.8059	0.8070	0.8080
54	0.8090	0.8100	0.8111	0.8121	0.8131	0.8141	0.8151	0.8161	0.8171	0.8181
55	0.8192	0.8202	0.8211	0.8221	0.8231	0.8241	0.8251	0.8261	0.8271	0.8281
56	0.8290	0.8300	0.8310	0.8320	0.8329	0.8339	0.8348	0.8358	0.8368	0.8377
57	0.8387	0.8396	0.8406	0.8415	0.8425	0.8434	0.8443	0.8453	0.8462	0.8471
58	0.8480	0.8490	0.8499	0.8508	0.8517	0.8526	0.8536	0.8545	0.8554	0.8563
59	0.8572	0.8581	0.8590	0.8599	0.8607	0.8616	0.8625	0.8634	0.8643	0.8652
60°	0.8660	0.8669	0.8678	0.8686	0.8695	0.8704	0.8712	0.8721	0.8729	0.8738
61	0.8746	0.8755	0.8763	0.8771	0.8780	0.8788	0.8796	0.8805	0.8813	0.8821
62	0.8829	0.8838	0.8846	0.8854	0.8862	0.8870	0.8878	0.8886	0.8894	0.8902
63	0.8910	0.8918	0.8926	0.8934	0.8942	0.8949	0.8957	0.8965	0.8973	0.8980
64	0.8988	0.8996	0.9003	0.9011	0.9018	0.9026	0.9033	0.9041	0.9048	0.9056
65	0.9063	0.9070	0.9078	0.9085	0.9092	0.9100	0.9107	0.9114	0.9121	0.9128
66	0.9135	0.9143	0.9150	0.9157	0.9164	0.9171	0.9178	0.9184	0.9191	0.9198
67	0.9205	0.9212	0.9219	0.9225	0.9232	0.9239	0.9245	0.9252	0.9259	0.9265
68	0.9272	0.9278	0.9285	0.9291	0.9298	0.9304	0.9311	0.9317	0.9323	0.9330
69	0.9336	0.9342	0.9348	0.9354	0.9361	0.9367	0.9373	0.9379	0.9385	0.9391
70°	0.9397	0.9403	0.9409	0.9415	0.9421	0.9426	0.9432	0.9438	0.9444	0.9449
71	0.9455	0.9461	0.9466	0.9472	0.9478	0.9483	0.9489	0.9494	0.9500	9.9505
72	0.9511	0.9516	0.9521	0.9527	0.9532	0.9537	0.9542	0.9548	0.9553	0.9558
73	0.9563	0.9568	0.9573	0.9578	0.9583	0.9588	0.9593	0.9598	0.9603	0.9608
74	0.9613	0.9617	0.9622	0.9627	0.9632	0.9636	0.9641	0.9646	0.9650	0.9655
75	0.9659	0.9664	0.9668	0.9673	0.9677	0.9681	0.9686	0.9690	0.9694	0.9699
76	0.9703	0.9707	0.9711	0.9715	0.9720	0.9724	0.9728	0.9732	0.9736	0.9740
77	0.9744	0.9748	0.9751	0.9755	0.9759	0.9763	0.9767	0.9770	0.9774	0.9778
78	0.9781	0.9785	0.9789	0.9792	0.9796	0.9799	0.9803	0.9806	0.9810	0.9813
79	0.9816	0.9820	0.9823	0.9826	0.9829	0.9833	0.9836	0.9839	0.9842	0.9845
80°	0.9848	0.9851	0.9854	0.9857	0.9860	0.9863	0.9866	0.9869	0.9871	0.9874
81	0.9877	0.9880	0.9882	0.9885	0.9888	0.9890	0.9893	0.9895	0.9898	0.9900
82	0.9903	0.9905	0.9907	0.9910	0.9912	0.9914	0.9917	0.9919	0.9921	0.9923
83	0.9925	0.9928	0.9930	0.9932	0.9934	0.9936	0.9938	0.9940	0.9942	0.9943
84	0.9945	0.9947	0.9949	0.9951	0.9952	0.9954	0.9956	0.9957	0.9959	0.9960
85	0.9962	0.9963	0.9965	0.9966	0.9968	0.9969	0.9971	0.9972	0.9973	0.9974
86	0.9976	0.9977	0.9978	0.9979	0.9980	0.9981	0.9982	0.9983	0.9984	0.9985
87	0.9986	0.9987	0.9988	0.9989	0.9990	0.9990	0.9991	0.9992	0.9993	0.9993
88	0.9994	0.9995	0.9995	0.9996	0.9996	0.9997	0.9997	0.9997	0.9998	0.9998
89	0.9998	0.9999	0.9999	0.9999	0.9999	1.000	1.000	1.000	1.000	1.000

Trade Literature
You Should Know About

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

The Truscon Laboratories, Detroit, Mich.—An interesting "Maintenance Chart" shows by a cross-section diagram of a building where the various Truscon maintenance products may be used in an industrial plant. These products include special preparations for walls, floors, ceilings and practically any application or treatment for steel or cement surfaces, and a special skylight and window cleaner.

Esterline-Angus Company, Indianapolis, Ind.—Bulletin 124 entitled "A Complete New Line of Graphic Instruments" announces the new model LR Esterline-Angus graphic meters which are made in wall type, switchboard type and portable type cases. They are also made with five hourly chart speeds which may be obtained by changing gears on the outside of the clock case. These speeds are ¾-in., 1½-in., 6-in. and 12-in. per hour. The construction and other features of the instruments are explained in the bulletin.

The Wireless Resistor Company of America, 1023-29 Coldspring Avenue, Milwaukee, Wis.—A booklet entitled "The Story of the Globar Element" describes the construction, characteristics and use of "Globar" which is a non-metallic electrical heating unit for industrial and domestic uses. This is claimed to be able to operate continuously up to 2,400 deg. F., and at higher temperatures for short periods. A number of industrial and domestic applications are described.

Diehl Manufacturing Company, Elizabeth, N. J.—Circular 1012 D-125 contains a brief description of the various types of Diehl motors, together with a condensed price list of the standard apparatus most frequently called for.

The Hayward Company, 50 Church Street, New York City—Pamphlet 620 entitled "Hayward Automatic Take-Up Reels" describes this special automatic take-up reel for use on electric motor-buckets and electromagnets in connection with locomotive and traveling cranes.

Mathias Klein and Sons, 3200 Belmont Avenue, Chicago, Ill.—Catalog 19 describes the line of Klein tools for electricians, linemen and mechanics.

American Schaeffer and Budenberg Corporation, Brooklyn, N. Y.—A 28-page catalog, No. 1400, describes the "American" spring pop safety and relief valve for stationary, portable and marine use.

The Humphreys Manufacturing Company, Mansfield, Ohio.—Bulletin 272 describes the points in the construction and operation of the Humphreys power pumps for miscellaneous industrial purposes. These are built for motor or gas engine drive.

The Phister Manufacturing Company, 717 Sycamore Street, Cincinnati, Ohio—A leaflet describes the Phister extinguisher, a 1-gal. carbon tetrachloride machine which is automatic in action. This extinguisher consists of a top and bottom casting of heavy brass to which is fastened an inner and outer brass shell forming two chambers. The outer chamber contains carbon tetrachloride and the inner chamber contains air under pressure, which when released into the outer chamber forces the liquids in a continuous stream a distance of 35 to 40 ft. through the discharge hose. Carbon tetrachloride is a non-conducting and non-freezing liquid which can be used on electrical fires.

Blue Seal Iron Company of Ohio, 554-55 Leader-News Building, Cleveland, Ohio—A small circular describes the use of Blue Seal Iron for making permanent patches and repairs. For example, the electrician can use it for repairing castings, motor frames, commutator ends, electrical fixtures, for electrical "ground work" and when joining wires which require more strength than is obtainable from ordinary solder.

Smith and Serrell, Central Avenue at Halsey Street, Newark, N. J.—A bulletin describes the "Keytite" self-fitting key. This is a special key made with a hardened steel cutting edge near the end to cut its fit into the keyway as it is driven in by a hammer. These keys are made with or without heads.

Grinnell Company, Providence, R. I.—An 82-page booklet on "Grinnell" adjustable pipe hangers gives description, dimensions and specifications of various pipe hangers and their applications. Several pages are devoted to instructions and information in regard to installing.

The Black and Decker Manufacturing Company, Towson Heights, Baltimore, Md. — An interesting catalog covers the Black and Decker portable electric tools and other shop equipment including electric drills, valve grinders, screwdrivers, electric bench and pedestal grinders, and electric air compressors. Phantom views show the construction and operation of the portable electric drill and other equipment.

Gillis and Geoghegan, 558 West Broadway, New York City—A new 24-page, two-color catalog illustrates actual installations of "G & G" telescopic hoists as used for handling ash cans, barrels, bales and other loads between floors.

Herbert Morris, Inc., Buffalo, N. Y.—Booklet 5041, entitled "Morris Machines to Lift and Shift," lists a wide variety of chain-blocks and illustrates some of their numerous applications.

Electric Furnace Construction Company, 1015 Chestnut Street, Philadelphia, Pa.—A folder describes the Soderberg Self-Baking Continuous Electrode adapted for stationary and tilting electric furnaces. In making these a raw mixture of carbonaceous material is tamped into a ribbed cylinder of light gage metal to form the electrode. As the electrode is consumed in stationary furnaces it is lowered into the furnace and new electrode casings added to the top. With tilting furnaces the electrode is removed and another inserted while the first is built up. A claim is made for saving in electrode cost and an increase in running time due to freedom from idleness while changing.

The North Electric Manufacturing Company, Galion, Ohio—A 16-page booklet describes the North Private Automatic Exchange for providing interior communication in factories, mills, railroad offices and shops, business houses and wherever instantaneous and accurate communication is needed. In addition to telephone service this system will provide for a conference arrangement, code-call system for locating executives, watchman service for the protection of the offices and plant, fire alarm system, warning of danger or emergency, annunciator service and pick-up service, which allows a call on one telephone to be answered on another in the absence of the called party.

The E. F. Hauserman Company, 1729 East Twenty-second Street, Cleveland, Ohio—A series of leaflets describe the Hauserman system of partitions, shelving and skylights. The partitions are designed particularly for foremen's offices and other small inclosures. The steel shelvings are available in a variety of shelves and pigeonholes, drawers and bins.

Wright-Hibbard Industrial Truck Company, Inc., Phelps, N. Y.—A folder describes the Wright-Hibbard type of elevating platform trucks. Some of the advantages claimed for this electric truck are a short turning radius, light weight and simplicity.

The Jeannin Electric Company, Toledo, Ohio—A 36-page booklet covers the construction, use and application of the Jeannin single-phase, repulsion-induction motors. Of particular interest is the short-circuiting device which operates when the motor is at rest or below normal speed.

Thermalene Gas Corporation, Kankakee, Ill.—A circular describes the Thermalene ideal goggles for use in welding. These are adjustable and so fixed that the lens may be turned up when not welding without removing the goggles.

Holophane Glass Company, Inc., 42 Madison Avenue, New York City—Booklet 375, entitled "Holophane Datalog" presents a large amount of data on illumination as compiled by the engineering department of this company from numerous investigations and study. A table gives the desirable illumination which should be provided for various locations in good modern lighting practice. Other topics discussed are: depreciation factor and maintenance; how to plan an installation; coefficient of utilization for each of the various types of reflectors manufactured by this com-

pany; a description of each reflector with various installation and engineering information concerning it; reflection factors of walls and ceilings; a description of the Holophane lightmeter, with special recommendations for its use.

Steel City Electric Company, Pittsburgh, Pa.—Catalog 34 is a complete catalog and price list of the various conduit fittings and boxes and other electrical supplies manufactured by this company and distributed through jobbers.

The Ohio Valley Pulley Works, Maysville, Ky.—A folder gives dimensions and prices for "Limestone" motor pulleys for motors, dynamos and similar work. This is a wood pulley built upon an iron hub.

W. T. Hunsdorf and Company, 720 Frankfort Avenue, Cleveland, Ohio.—Small circulars describe the high speed "Pin-Coil Winder" which is claimed to have quick adjustment and to be easily operated in the winding of pin-wound coils. This winder is equipped with turn counter and multiple wire grip. Another folder describes the coil duplicating machine which is used for converting pin-wound coils into high-grade "knuckle-type" coils for armature or stator work.

Hasler-Tel Company, 461 Eighth Street, New York City—Folders describe the "Hasler Speed Indicators." These speed indicators are provided with three pointers, one for centered shafts, another for uncentered shafts and a third with a small wheel which is used to measure the circumferential or linear speed. The first two are used to obtain r.p.m. and the third in measuring surface speed in feet per minute as on beds of machines or material in lathes.

The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.—Publication 3062 entitled "Electric Conduction Heaters," describes and illustrates the application of electric heat on metal pots, metal molds, embossing press heads, gluing machines, package sealing machines, thread finishing machines, shoe and textile machines, celluloid dies and other general industrial and machine applications. Various types of heater construction are discussed, with the possibilities of applying electric heat to many industrial processes.

Foamite-Childs Corporation, Utica, N. Y.—Folders describe the Foamite equipment for smothering stubborn fires in oil, gasoline, paint- and varnish-dipping tanks, quenching tanks, and the like.

The L. S. Starrett Company, Athol, Mass.—A revised supplement to Starrett Catalog 22 on "New Starrett Tools" lists additional special machinists tools and is issued supplementary to the general catalog.

The Schatz Manufacturing Company, Poughkeepsie, N. Y.—Catalog 8 lists the "Commercial" annular ball bearing rollers of both regular and special types. These balls are not ground and are intended for a wide variety of uses under moderate speed and light duty. Some of the industrial uses are on gravity roll conveyors, trucks, grindstones, sliding doors, belt conveyor rolls, casters, and a wide variety of machines.

Reliance Electric and Engineering Company, Cleveland, Ohio—Bulletin 2014 describes the Type T Reliance motors for direct current. In addition to a general discussion on why a more rugged, general-service motor is required, a number of illustrations is given of each of the types of motors and also of each separate part. Additional illustrations give the method of assembling. The largest of these motors are made with split frames if desired. A large number of installations on a variety of applications are included.

W. A. Jones Foundry and Machine Company, 4401-51 West Roosevelt Road, Chicago, Ill.—Catalog 27 contains much valuable information on cast-iron, steel, wood and paper pulleys, such as the weights and extra lists for special types and rubber coverings. It also describes, illustrates and lists "Lemley" ball bearing loose pulleys and ring-oiling loose pulleys.

C. J. Tagliabue Manufacturing Company, 18-88 Thirty-Third Street, Brooklyn, N. Y.—A folder describes the "Tag" shutoff valve which is connected in the fuel lines of oil burners and other similar devices to automatically cut off the oil flow the instant that the steam or air pressure used for atomizing falls below the required minimum.

The Johns-Pratt Company, Hartford, Conn.—A special folder shows the construction of the "Noark" universal service switch. This uses plug fuses which may be removed without opening the switch.

The Thermal Syndicate, Ltd., 350 Madison Avenue, New York City—A booklet entitled "Vitreosil Data" describes the electrical insulating value and use of "Vitreosil", which is a fused quartz or silica, as well as its other applications in laboratory and chemical work.

Acheson Graphite Company, Niagara Falls, N. Y.—A small folder describes the Acheson welding electrodes for graphite arc electric welding and cutting and gives sizes and prices. A page is devoted to Acheson graphite plates for use in backing up welds.

Westinghouse Electric & Manufacturing Company. Pittsburgh, Pa.—A 24-page booklet entitled, "A Material of Endless Possibilities," contains information about "Micarta" and the many uses to which it has been put and the possibilities of some other applications.

Century Electric Company, St. Louis, Mo.—Form 366 is a small booklet describing the Century squirrel-cage-induction polyphase motors and some of their various applications.

Burke Electric Company, Erie, Pa.—Bulletin 128 describes the types of polyphase induction motors, gives the details of construction and also illustrates a number of their industrial applications.

Ward Leonard Electric Company, Mount Vernon, N. Y.—Bulletin 57 describes the Vitrohm speed regulator of the fully-enclosed type which is designed for use with all types of constant-torque, direct-current motors up to ⅓ hp., 115 or 230 volts, and with variable-torque motors up to ½ hp. rating.

Hauck Manufacturing Company, 114 Tenth Street, Brooklyn, N. Y.—Catalog 100, "Hauck Oil Burning Appliances" shows a wide variety of applications of this equipment in boiler shops, for brazing in coppersmith and pipe shops, in foundries, for furnaces and forges, in machine and repair shops for straightening, heating, brazing and pre-heating for welding, for removing disks, gears or pulleys from shafts by expanding hub, for thawing and for many other industrial applications in factories, foundries, railroad shops, machine and repair shops, shipyards and docks. Bulletin 112 gives special applications of the Hauck burner for foundries, boiler, machine and repair shops.

North Western Expanded Metal Company, Old Colony Building, Chicago, Ill.—A 16-page booklet entitled "Practical Machine Guards" shows how these may be constructed from "Econo" expanded metal by fastening the corners and edges together with angle iron, flat strips, or U-edging. The expanded metal comes in sheets and can be cut to fit the specific requirements of the guard.

The Robbins and Myers Company, Springfield, Ohio—Bulletin 137 describes the construction, operating characteristics, and gives general information, including the ratings and dimension sheets for the R. & M. types "R" and "RA" repulsion-induction motors. These are specially suitable for driving devices such as pumps, compressors, shoe-repairing machines and all other apparatus requiring high starting torque with low starting current.

The Goodyear Tire and Rubber Company, Inc., Akron, Ohio.—A 64-page "Handbook of Conveyor and Elevator Belting" is a handbook well worth being in the hands of every industrial engineer having to do with conveyor or elevator belts. Because of the variety of conditions and requirements, these are handled separately. Such subjects as capacity, width, weight per foot of belt, tension in belt, power required, number of plies required, take-up and counter-weights, idlers, belt joints, service records, and how Goodyear rubber conveyor belts and elevator belts are made, in addition other interesting data are included.

The Fuerst-Friedman Company, 1251 West Third Street, Cleveland, Ohio—No. 2 of a series of "Motor Instructions and Trouble Locator" cards which may be hung up in the shop, is entitled "Proper Fusing" and gives a table showing the ampere rating and sizes of running and starting fuses for three-phase, alternating-current motors, 220, 440, 550, and 2,200 volts, from ¼ to 500 hp. No. 1 of the series took up some of the important points to consider in the installation of motors.

The Hartford Steam Boiler Inspection and Insurance Company, Hartford, Conn.—A folder entitled "Insurance of Electrical Machinery" describes the advantages of protection against loss arising from the breakdown of electrical machinery. This folder tells what the insurance is and what it will cover.